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ABSTRACT

This report focuses on technical issues associated with informatics--a term covering all aspects of the development and operations of information systems, the supporting computer methodology and technology, and the supporting telecommunications links. The first of six chapters discusses the purpose of the report together with basic assumptions about health care systems as related to informatics and the use of computer-based information processing and transfer in telecommunications; key computer applications in health; and current trends in these rapidly evolving technologies as they apply to health. Subsequent chapters deal with national health informatics policy and strategy; informatics support for health programs and in the provision of health care; informatics for health manpower development; and the choice of informatics technology. It is concluded that informatics will be increasingly used in all organizations and that its use must be managed. Three annexes contain a list of participants in the international consultation on application of informatics; brief descriptions of sample curricula; and an eight-page glossary. (CGD)

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Informatics and Telematics in Health

Present and Potential Uses

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World Health Organization
Geneva

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By means of direct technical cooperation with its Member States, and by stimulating such cooperation among them, WHO promotes the development of comprehensive health services, the prevention and control of diseases, the improvement of environmental conditions, the development of health manpower, the coordination and development of biomedical and health services research, and the planning and implementation of health programmes.

These broad fields of endeavour encompass a wide variety of activities, such as developing systems of primary health care that reach the whole population of Member countries; promoting the health of mothers and children; combating malnutrition; controlling malaria and other communicable diseases, including tuberculosis and leprosy; having achieved the eradication of smallpox, promoting mass immunization against a number of other preventable diseases; improving mental health; providing safe water supplies; and training health personnel of all categories.

Progress towards better health throughout the world also demands international cooperation in such matters as establishing international standards for biological substances, pesticides, and pharmaceuticals; formulating environmental health criteria; recommending international nonproprietary names for drugs; administering the International Health Regulations; revising the International Classification of Diseases, Injuries, and Causes of Death; and collecting and disseminating health statistical information.

Further information on many aspects of WHO's work is presented in the Organization's publications.

INFORMATICS AND TELEMATICS IN HEALTH

Present and Potential Uses

World Health Organization

Geneva

1988

In order to ensure prompt distribution, this book has not received such detailed editorial revision as most other WHO publications

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FOREWORD

The recent developments in computer and telecommunications technologies have given significant impetus to the provision of, and demands for, more information support in many different fields. These developments have been used to support good cost-effective management and technical work. But the potential of informatics and the opportunities it creates are of far-reaching significance - so much so that some have referred to the "informatics revolution". Informatics has already changed the lifestyles of individuals and societies, and indeed the economic growth patterns of whole nations. Its influence on every aspect of life promises to be as profound as that of the industrial revolution.

The use of informatics in the health sector has expanded enormously over the past five years. Most applications have been in the medical field, with less change in other fields, such as community and public health. Considerable interest in the potential of informatics has been expressed by the staff of national health authorities. Indeed, there is an increasing awareness of the potential of informatics for improving the quality and cost-effectiveness of health services and support activities.

Recognizing these developments, in January 1985 the Executive Board of the World Health Organization requested that a report be produced to assist national health authorities in answering the following questions: for what purposes, where, and how can informatics be used in the health sector? and how should informatics systems be introduced and managed in order to maximize the benefits to health services? A draft report was issued in November 1986, mostly based on consultations with senior health administrators and informatics experts from national institutions, including WHO collaborating centres in health informatics. The present version has been updated to reflect the rapid evolution of informatics technology and its increasing and evolving uses in the health sector.

Informatics, if properly used, can increase the efficiency and cost-effectiveness of health services. It is hoped that this book will help the staff of health services to appreciate the way in which informatics technology has developed and the ways in which it may evolve in the future, as well as providing an overview of the many existing and anticipated uses of informatics in the health sector.

Dr Salah H. Mandil
Director, Division of
Information Systems Support
World Health Organization

Chapter 1

Introduction

The purpose of this report is discussed together with basic assumptions about health care systems as related to informatics and telematics. The chapter also highlights key computer applications in health and identifies the current trends in these rapidly evolving technologies as they apply to health.

1.1 BACKGROUND

Health informatics is a relatively recent technology which is rapidly being introduced into health systems around the world, especially since the advent of microcomputers. Recognizing these developments and the potential benefits they hold out for countries, the WHO Executive Board in January 1985 called for a report to be produced that would assist national health administrators in making efficient and appropriate use of informatics in health, especially for information systems supporting the monitoring and evaluation of health services.

In response to this request, the present report was produced by the Consultation on the Applications of Informatics in Health. Convened in December 1985, the Consultation was attended by national informatics experts, senior health administrators responsible for health informatics services, representatives of the WHO Collaborating Centres in Health Informatics, and members of the WHO Secretariat as shown in Annex 1. The aim of the report is to help public health administrators and health managers to decide: (i) for what purposes, where, when and how informatics may be used in health services, and (ii) how to manage these services in order to benefit most from informatics. The main target group for this report is therefore the top managerial levels of the permanent professional staff of health ministries, secretariats, or equivalent. Other health professionals to whom the report is directed include :

(a) the main providers of information;
(b) health informatics specialists;
(c) the principal users of information; and
(d) technical staff responsible for significant applications.

The report can also be useful as an introductory text in health informatics.

Annex 3 gives a glossary of the main terms used in the report. Readers not familiar with computer terminology will find it useful to brief themselves on the key terms (shown in capital letters) before reading on.

1.2 ASSUMPTIONS

1.2.1 Health Care Systems

In deliberating on the subject of informatics in health, the Consultation was acutely aware of the differing status of development and organization of health care systems in different countries. Most countries have some form of managerial process for national health development and many have plans with definite objectives and strategies for implementation, according to established time frames, but they differ in their targets and priorities, the scope and structure of

their health care systems, their methods and levels of funding, as well as in the sophistication and detail of their planning processes.

It is assumed that some form of health care management structure, with defined focal points of accountability and decision-making, exists in all countries. In the health sector as elsewhere, managerial decision-making requires reliable, relevant and timely information. Informatics, which may already be in use in other sectors of the national economy, can serve as a useful tool for providing this information. It should be recognized, of course, that the introduction of informatics will itself cause major changes in the organization of the health care system. Better information may lead to pressure for different decisions from previously uninformed individuals and groups.

The belief that only developed countries can afford computer technologies is a misconception. Informatics is not free, of course, but at today's prices, with a complete microcomputer configuration (computer, printer, etc.) costing under US$5000, its use can be considered by all. The investment required in human resources to develop and use informatics is usually more costly.

By choosing appropriate entry points and the right mix of technologies and resources, even developing countries can afford and benefit from the current explosion in informatics technologies. To obtain maximum benefit from these recent advances, however, it is necessary to establish a national health informatics policy and strategy, and to prepare the health system for the appropriate use of the new technologies.

Since the adoption of the Global Strategy for Health for All by the Year 2000 by the World Health Assembly in 1979, WHO's Member States have agreed on global, regional and national strategies and on very specific targets. Health-for-all strategies, especially in developing countries, place great emphasis on the development and strengthening of primary health care services and on efficient management systems at the district level. In each country, informatics policies and applications must be tuned to these strategies and be compatible with the prevailing conditions and resources available.

AT-A-GLANCE

- Decision-making in health care management depends on reliable, relevant and timely information.
- Informatics is a useful tool for the management of the health care system.
- All countries, including developing ones, can benefit from informatics
- Effective implementation of health informatics in any country or organization requires the establishment of policies and strategies.

1.2.2 Computers and Informatics

Information can be stored, manipulated, and retrieved quickly and efficiently with computers. In large computer systems, a single magnetic disk can easily store more than 100 000 pages of text. This is roughly equivalent to four rather large encyclopaedias or over 300 books of more than 300 pages each. A huge storge capacity is now available for microcomputers also, thanks to optical disks or Compact Disks/Read Only Memories (CD/ROMs), using laser technology. One CD/ROM can store the equivalent of more than 730 books of some 300 pages each.

Besides occupying significantly less physical space, information on disks can be retrieved at a speed several orders of magnitude faster than with methods which use other devices for bulk storage of information, such as paper and microfiche. Also, computers permit virtually direct access to the precise set of information desired, provided the information is appropriately indexed. It used to take hours, days, and even weeks

to retrieve and consolidate information. The same function can now be completed in a few minutes by a computer.

Today, a microcomputer can put at the disposal of an individual about the same basic computing power as a mainframe computer did in the 1960s and a minicomputer did in the 1970s. Mainframe computers are now used principally to handle very large data volumes, such as a national health information data base. The minicomputers introduced in the 1970s are nowadays most appropriate for a department or division or even a working group within a large organization. Microcomputers are ideally suited as work stations for individuals. However, by interconnecting a series of microcomputers through a local area network, it is feasible to generate enough computational power to meet the needs of an entire organization.

A computer receives, stores, processes and communicates information by breaking a task down into logical operations that can be carried out with binary numbers - strings of 0's and 1's - and by doing up to a thousand million operations per second. At the core of the computer is the central processing unit (CPU), consisting of scores of interconnected electronic components. In a microcomputer, the CPU consists of a single electronic element - a "chip" - that is typically about a centimeter square. This is the true "brain" of the computer, carrying out the computations and comparisons, supervising everything that is being done by sudsidiary chips, and controlling the traffic or information between the various parts of the system. Other electronic elements constitute the computer's primary memory, where both instructions and data can be stored.

Information can be entered into the computer usually by means of a keyboard or by means of transfer from storage devices(magnetic tapes or disks). The computer's output is displayed on a screen, called a monitor or video display unit. The output can also be printed on paper by a printer unit. A modem (**mod**ulator-**dem**dulator) can be attached to convert the computer's digital signals into signals for transmission over telephone lines.

These various electronic elements and the many other peripheral devices which can be attached to them constitute the computer's hardware. The hardware can do nothing by itself: to work, it requires an array of programs, or instructions, collectively called software. The core of the software is an "operating system" that controls the computer's operations and manages the flow of information. The operating system mediates between the machine and the human operator and between the machine and an "application" program that enables the computer to perform a specific task: calculate a payroll, edit a letter, or draw a picture.

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1.3 TRENDS IN INFORMATICS

Informatics may be defined as the combination of technology and methodology which makes possible the computer-assisted collection, storage, processing, retrieval, distribution and management of information. In this report the

term "informatics" is used to refer to both informatics and telematics, i.e., the use of informatics in telecommunications.

The spectrum of computer-based applications is becoming ever wider thanks to the rapid growth in the power of computers and the sharp decline in their prices. If the aircraft industry had evolved as spectacularly as the computer industry over the past 25 years, a Boeing 767 today would cost US$500 and could circle the globe in 20 minutes on twenty litres of fuel. This popular analogy illustrates the reduction in cost, the increase in speed of operation, and the decrease in energy consumption of computers. The cost of computer logic devices has been falling by 25 % a year and the cost of memory devices by 40 % a year. Computational speed, on the other hand, has increased by a factor of 200 in 25 years.

Informatics and telematics have been with us for a comparatively long time, but it is only in the past few years that the information revolution has become really visible. The industrialized countries have made substantial progress in the use of informatics. Consequently, they have benefited in many areas of endeavour, not least in the provision and management of health services. In most developing countries informatics is grossly neglected. There is considerable disparity between developed and developing countries in terms of the extent and the nature of their use of informatics. It has been estimated that Third World countries, which represent about 80% of the world population, account for only 2% of the total global expenditure on informatics and electronic information handling. A study carried out in 1986 revealed that 5.7% of the world's computers are installed in Asia, Africa and Latin America, and half of these are in Latin America. However, several developing countries are proceeding rapidly in this field and within 20 years some of them may overtake many currently industrialized countries in this technology.

Furthermore, there has been a recent acceleration in the development of informatics technology and informatics systems. Their utilization 10 years from now will certainly be quite different from what it is today. Therefore, considering the time it takes to train personnel to design and operate health systems, especially in the professional categories, there is an urgent need to orient the teaching of health informatics to future applications, equipment and methods. This could be achieved by closely integrating research and education.

During the last 25 years, uses of informatics in health have changed considerably. The operation of health care systems has benefited from versatile informatics tools supporting both the multiple demands of patient care and the needs of clinical and administrative decision-making. This report presents and projects these trends by describing forthcoming technologies and the changing needs of health services and systems for informatics support - for instance, for improved communication, for more intersectoral cooperation, and for well informed decision-making at all levels of the health services. The report further stresses the necessity for associating research with education, especially in developing countries. Also in planning new applications, it is necessary to ensure that they will both satisfy health services requirements of the future and take advantage of forthcoming technologies.

1.4 APPLICATIONS OF INFORMATICS IN HEALTH CARE

The transfer of computer-based health care applications from developed to developing countries is a delicate issue which is not always given due consideration, especially by enthusiastic vendors or consulting firms. The transposition of a system from one country to another, without a thorough analysis of the situation and requirements often results in an inefficient system and consequently in wasted resources and frustrated users.

Most countries - developed and developing - suffer from an abundance of unanalysed data with limited relevance to strategic planning and to the management of health services and programmes. It has repeatedly been said that informatics in health, especially in developing countries, can-

not be regarded as an isolated discipline and technology but must be viewed as an integral and essential element of the managerial process for national health development. In this connection, it should be noted that the rationalization of managerial procedures that is a prerequisite for computer use will often yield important benefits irrespective of the eventual automation of the process. Recognition of the importance of the management sciences in the rationalization of operational and administrative activities is indispensable. Many health care delivery problems can be directly related to the appropriate, effective and efficient use of resources.

An important area for the development of informatics in health is the management of health services and programmes at the district level. Computer networks connected through adequate telecommunication services can be important tools to this end, and great progress has been made in recent years in installing reliable telecommunication networks in several developing countries. In addition, work is going on in several places to develop appropriate information systems giving measures of the efficiency and outcome of the health care delivery process.

The health worker of the year 2000 is likely to be a person with immediate, transparent access to a large amount of data along with analytical decision support routines to assist him/her in decision-making. This fact has far reaching consequences not only for the training of health personnel but also for the organization and management of health programmes.

It cannot be overemphasized that **national policies and strategies** for the development of informatics in health and for the solution of the related standardization and organizational problems are fundamental for sound, cost-effective development. Numerous and often dramatic examples could be quoted of failure of informatics applications because of disregard of these policy and strategy issues. There is a need to tune health informatics policies and strategies to national informatics policies and strategies.

AT-A-GLANCE

* Computers can store, manipulate and retrieve large amounts of information quickly and efficiently.
* Information stored in computers may be transmitted through telecommunication links (cables, telephone lines, satellites, etc.).
* Informatics is becoming increasingly inexpensive, but there is still a large disparity in information processing expenditures among countries.
* Successful transfer of computer-based applications in health from one environment or country to another requires care.
* Enlightened policies for informatics personnel are of paramount importance.

Informatics also has a definite role in the **training and education** of health workers. In many countries health workers will have to use informatics in their daily work and will thus need to be taught how to handle informatics tools and use them to maximum advantage. Experience has also demonstrated the effectiveness of computer-assisted education and refresher training in teaching a variety of subjects, particularly in educational programmes with inflated curricula.

The development of applications should focus on those areas of greatest relevance to health-for-all strategies. Later chapters will consider the formulation and implementation of national policies and strategies for informatics in health and their integration with both health and overall informatics policies and strategies. In-

creased informatics support will be needed especially for primary health care programmes, including direct assistance to community health workers and leaders. Informatics support for the management of local health services at the district level is also of major importance, and suitable examples are cited in Chapters 3 and 4.

1.5 ORGANIZATION OF THE REPORT

The report contains a general overview of informatics in health, citing specific applications. It also deals with general policy and strategy issues, and reviews present technology choices and future prospects. It comprises seven chapters and three annexes.

Chapter 1 sketches the background of the report and gives an overview of trends in informatics and its applications.

Chapter 2 deals with national health policy and strategy. It emphasizes the importance of formulating such policies and strategies.

Chapter 3 deals with informatics support for health programmes. It outlines the specific support required at various levels of management. It gives some examples of major applications of informatics in health, chosen because of their importance in the management of the health care system.

Chapter 4 discusses the informatics support used in the care of the individual both in the organized health care system and in self-care and community care. It deals also with computer assistance to decision-making in health care on subjects such as statistics, epidemiology and literature retrieval.

Chapter 5 analyses the issue of human resources for health informatics. It emphasizes the importance of appropriately trained personnel in the development and operation of informatics. It shows, in addition, how computers can be used as tools to increase the efficiency of training and education in other subjects.

Chapter 6 addresses itself to some basic elements in the selection of adequate informatics technology, although it does not provide all the detailed considerations needed to make actual choices.

The ***Epilogue*** highlights some issues not considered elsewhere in the report. Annexed to the report are a list of contributors, sample curricula in health informatics, and a glossary of terms.

Chapter 2

National Health Informatics Policy and Strategy

The situations which lead to the need for a national health informatics policy and strategy are discussed. The essentials of a policy are reviewed, including both standards and financial, material and human resources. Likewise, the need for and contents of an implementation strategy are discussed, together with essential and recommended applications, and the development of personnel and standards.

2.1 INTRODUCTION

"Informatics is expensive."
"Informatics is disruptive of administration."
"Informatics lets me do my real job."

These and other statements are sometimes heard, and there is some truth in each of them. Certainly, countries that have developed computerized information systems within their health services have had to apply significant resources and managerial energy to the task. The evidence indicates that this investment has been well worth while. This does not automatically mean, however, that all nations should follow suit to the same extent. Each should consider for itself whether informatics systems are appropriate to it and, if so, what kinds of systems it should examine and on what timetable it should proceed.

"The Export Trading Company is upgrading its equipment and will give us its old computer free."

"We have US$40 000 left in the budget. Let's buy a computer with it."

"Dr Part learned how to use a System 88 on his training fellowship and wants one for his department."

"The planning committee needs guidance on whether a computerized system for hospital statistics or an accounting system should receive priority."

"The MCH department has completed a requirements analysis and feasibility study and is seeking approval for a complete hardware/software system."

All of these options and more may well be under consideration simultaneously in any health organization. How can we decide on them collectively and individually? How do we avoid wasting scarce financial and human resources? How do we avoid duplication of effort and the incompatibility of systems? How do we ensure that training is directly relevant to our future systems? In the face of such situations and questions, it should be clear that every complex organization needs an information policy and strategy.

The overall objective of health informatics is to meet information requirements at all levels of the health services for purposes of:

- policy formulation and programming;

- implementation, i.e. supporting the provision of health care and disease prevention;
- monitoring and control.

Until recently, there were differing underlying technologies for the various information services. For example, the technologies for typing and editing text, for producing the text as a document or publication, for preparing graphs and pictures to be added to the document, and for disseminating the document to its various destinations were totally different. Such differences in the underlying technologies of information services were used to explain the operational inconveniences and relatively high costs of the traditional means of providing the services. The inconveniences and costs of the fragmentation and incompatibilities of office support have had to be met because they appeared to be unavoidable.

Today, they are avoidable. Modern information services, such as word processing, information processing and retrieval, graphics, document production, data transmission, facsimile, telex, telephone, etc., are based on one underlying technology - digital computer technology. Economies in the costs and improvements in the efficiency and quality of these services depend on a high level of compatibility and integration of the computing support to these services.

Health informatics makes appropriate use of technology to provide information in a cost-effective manner. The policy and strategy for health informatics must reflect the environment in which they will operate. They must be appropriate to the technological status of the country, reflect the financial and human resources available, and meet the timing constraints often imposed from elsewhere.

2.2 THE NEED FOR A NATIONAL HEALTH INFORMATICS POLICY

A policy establishes the rules an organization must follow in carrying out its work. Establishing a health informatics policy helps to ensure that development and use of systems will proceed in a coordinated manner. The health informatics policy must be in consonance with any overall informatics policies in force in a country as well as with its overall health policies. The national health informatics policy, in turn, sets limits to any policies that may be established lower in the hierarchy, at regional or local levels.

Once formulated, a policy must be implemented in a coordinated manner. It may be necessary or convenient to establish a formal organizational entity to coordinate implementation. Such a group may be charged with formal coordinating functions, such as:

(a) Conducting surveys and research on the implementation of health informatics activities in programme areas suitable for computer utilization;

(b) Taking measures to solve problems that stand in the way of computer utilization and establishing systems and procedures for assistance to national, regional and local agencies active in health informatics;

(c) Promoting training of computer personnel and coordinating system-wide training programmes;

(d) Conducting research into computer-sharing and promoting the joint use of computers, computer files and software in order to diminish costs and establish an interorganizational network of information systems;

(e) Preparing and disseminating policies and guidelines on the requisition and use of information resources.

The coordinating group must strike a balance between indiscriminate or unregulated use of computer resources and overly rigid procedures that may hinder effective development.

A health informatics policy may require legislation, operational regulations, and guidelines. As part of a national informatics policy, it should establish linkages, common standards, procedures, etc., for sharing of information with other sectors. It should support established priorities, both general and in health.

AT-A-GLANCE

* Health informatics offers appropriate technology to meet information requirements at all levels of the health services in an effective and efficient manner.
* Health care managers require a policy and strategy to guide their day-to- day decisions on the use of informatics in their organizations.
* The health informatics policy chosen must be in consonance with any overall informatics policies as well as with health policies at the national level.
* Coordination of the implementation of the health informatics policy may be assigned to a formal organizational entity.
* The policy must establish common rules, such as standards, priorities and guidelines, and prepare the way for compatible legislation and regulation.

2.3 ELEMENTS OF A NATIONAL HEALTH INFORMATICS POLICY

A policy must first of all support national goals and objectives in informatics and in the health sector. Within these objectives, particular attention should be given to the sharing and exchange of information, the relative priority of different projects, the education and training of health professionals in informatics, the impact of informatics on the health services, the issue of centralization and decentralization of information systems, the problems of data security and privacy, the definition of the rights and levels of access, and the methods for choosing appropriate supportive technology.

National policies will play a key role in the development of informatics. Established policies control managerial mechanisms, allowable technological solutions, and resource levels.

Managerially, health informatics must reflect the policies and practices in use. Informatics is not, however, simply subservient to established methods as a new health programme might be. Information is a unique commodity and the provision of information requires special attention. All organizations have difficulty in assigning responsibilities for informatics within established managerial structures. In addition, the use of informatics itself permits, and sometimes imposes, new approaches to the management of organizations.

At the policy level the technological considerations are concentrated on the need for standards. The most obvious rationale for standards is that they facilitate the exchange of data. Almost as important as the exchange of data is the transfer of programs from one computer to another, made possible by language standards. Communication between computers, which is becoming increasingly important, requires standards for hardware, software and communication protocols.

Standards are needed to ensure the reliability and security of data.

Standards are also necessary in such areas as

systems design, documentation, program development, program testing, and training. Though they may sometimes be seen as an obstacle to productivity, formal standards have a positive function in encouraging the development of a truly interacting system. Standards are discussed in section 2.5.5 and in some detail in Chapter 6.

Resource policies must address the traditional issues of human, financial and material resources. The human resources required should be clearly identified. Frequently the required personnel is in short supply. Therefore, policies on personnel recruitment, education and development should be part of the informatics policy. Personnel retention, and consequently continuity in procedures and work, is a major problem in many developing countries. These issues can be addressed only within the context of appropriate regulations, procedures and guidelines on human resources. Chapter 5 reviews the question of human resources at length.

Financial policies must follow established government policies. The vital issue of the extent of user payment versus central budgeting must be resolved for both capital and recurring expenses associated with informatics.

These considerations carry over into material resources. Who owns and operates the computer and communications resources in use? Are policies needed for such vital support as consumable supplies and maintenance? The handling of informatics and telematics resources may require some deviation from the normal policies for handling government-owned equipment.

2.4 THE NEED FOR A HEALTH INFORMATICS STRATEGY

A strategy is a set of activities and/or programmes chosen in order to achieve long-range objectives. It delineates directions to be followed, so that all involved can work cost-effectively and in unison. It gives the time goals for activities and contains provision for strategy updating. Whereas a policy sets down the rules, a strategy describes what will be done within the context of those rules. In the area of health informatics, the policy creates a framework from which strategies are to be derived. In the formulation of policies and strategies at the national level, regional and local contributions must be considered. Once formulated, however, these national policies and strategies will provide the framework within which more detailed strategies and targets can be developed at lower hierarchical levels.

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Elements of a Health Informatics Policy

* Definition of technological standards to facilitate communication and the sharing of data between computers.
* Definition of measures and standards for ensuring reliability, privacy, and security of data.
* Definition of policies for human resources development, allocation and utilization.
* Definition of constraints on financial and material resources.

A major strategic objective is the elimination or reduction of deficiencies in the quantity, quality and relevance of data and of the timely access to information. The implementation strategy should address issues such as:

(a) improvement of communication and collaboration among managers, informatics professionals, and end-users of information;
(b) major decisions to be made regarding future needs, allocation of informatics resources, and standards of compatibility;
(c) priority of various applications, considering such criteria as return on investment, needs

for health care delivery, and logistic, administrative and managerial support;

(d) avoiding and/or eliminating "automation islands", i.e, systems that cannot be integrated with other systems;

(e) maintaining a technological balance of hardware and software among users.

Periodic strategy development or updating is required to respond to new and increased requirements of users, to reflect changes in the country's health sector, and to take advantage of the continued improvements and cost reductions offered by technology.

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* Strategy encompasses the specific plans for policy implementation, e.g., acquisition and development of hardware and software, the implementation of standards, and support to human resources.

* Health informatics requires periodic updating of strategy in order to reflect changes in technology and in user requirements.

2.5 ELEMENTS OF AN INFORMATICS STRATEGY

Since it is apparent that strategies will differ from one country to another, and between health authorities within a country, this report will not attempt to prescribe what a strategy should be but will discuss the subjects that may form part of a strategy and indicate how these can be beneficial. The subjects are systems, applications, distribution of responsibilities and resources, skills, and standards of compatibility.

2.5.1 Systems

The strategy must outline the "architecture" of the systems, upon which development will proceed. Such an architecture should have the following elements specified, to the level of detail consistent with the established policies:

(i) hardware;
(ii) software;
(iii) methods for developing applications;
(iv) communications protocols.

The hardware strategy must give consideration to the type of computers (mainframe, minis and micros), their peripheral devices, and their interlinking. This should be specified to the level of detail thought most appropriate.

The software strategy must specify the system software (e.g., operating systems) and programming languages to be used, as well as software packages and tools, such as data base management systems, spreadsheets, statistical, bibliographic and graphic packages, or specially developed software. These specifications are essential for compatibility, which in turn is vital for economics, ease of use, and productivity.

Methods must include the procedures to be followed for the development of applications. Recently, more attention has been drawn to the need for protection of data. Ensuring the integrity and confidentiality of data must be part of the procedures for application development.

Adherence to specified communications protocols ensures that individuals, systems and applications can communicate with each other.

2.5.2 Applications

Later in this report, some examples are given of how informatics can be applied to provide support for health management. Clearly, it is neither economically nor practically feasible to implement all possible applications. Equally, any positive national strategy will require an essential minimum of applications.

Essential applications. These are the applications of informatics and telematics that are con-

sidered of utmost necessity and/or highest priority for the implementation of health policies at local, regional and national levels. Requirements imposed at a higher level often call for cooperation by elements at a lower level of the organization. For example, a computer-based application may be required to support a national health objective such as an intensive immunization campaign against a particular disease. National health authorities will wish to determine which are the essential applications to be developed. Regional levels may further define essential applications for the local authorities within that region.

Recommended applications. Once the essential applications have been developed, each authority will determine what other applications it will develop, in line with its strategy and comprehensive policies, and depending on the availability of resources and skilled expertise. Recommended applications may be concerned with the economical use of resources (e.g., supply systems), with better administration (e.g., office automation), or with the logistics of patient therapy (e.g., pharmacy control systems).

2.5.3 Distribution of Responsibility and Resources

Any complete strategy for achieving a set of objectives must describe the lines of responsibility and the resources to be made available. Those responsible for activities within the defined strategies must ensure that the human, financial and material resources necessary to carry out their role will be available at the proper time.

As with all complex organizations seeking to achieve both local and more general objectives, there should be a clear understanding of the responsibilities involved. Health services, unlike most other endeavours, have an additional complicating factor because of the potential clashes between those with responsibility for individuals (i.e., involved in direct patient care) and those with responsibility to the organization and the community at large (managers). It is important that national health service authorities establish clear lines of responsibility. Consultation is essential for the establishment of the strategy at each level.

2.5.4 Skills

It is well known that the key to success in any task lies in the quality and skills of the people involved, as well as in their continuity in the task. This applies equally to informatics, but it must be remembered that in this field some degree of knowledge and skills on the part of the users is also necessary. An informatics strategy, therefore, requires identification and measurement of these needs, and plans to satisfy it. Chapter 5 elaborates on the issue of human resources development for informatics.

Human resources requirements. In considering the requirements for expertise in the field of informatics (i.e., systems and programming staff, telecommunications personnel and, above all, specialized professional management), an assessment must be made of the numbers, levels of experience and balance of skills required. Such assessment may refer to other organizations within a national economy that have already instituted similar programmes.

Human resources assessment. The next task is the assessment of the gap between the short-term requirements and the existing situation in human resources. For this, a survey may be needed.

Human resources development. From the basic assessments made of the existing resources and the skills needed, a human resources development plan can be prepared. The human resources needs can be met by these key elements:

- *Awareness programmes*: The health informatics strategy is likely to have a considerable impact on the management structure of the health services. Thus, management will need to be aware of the advantages and disadvantages of informatics, its benefits and pitfalls, and the extent of their own involvement

and responsibilities in the introduction of informatics. Many of the problems that result from this introduction derive from lack of awareness on the part of management, particularly senior management. Thus, the strategy must ensure that managerial staff at all levels are properly informed in order to promote a receptive and forward looking attitude.

- *Education of health professionals*: Most of the different professions active in health services will be involved to some extent in the use of informatics. This involvement may be limited to providing input data only, in the case of some professionals, but it is likely that many professionals will benefit from the direct use of informatics in their work. Provision needs to be made for the education and training of these professionals in informatics. In many cases, introductory courses, such as the awareness programmes cited above, will be sufficient. For other staff (e.g., medical staff using patient monitoring systems and pathologists working in automated laboratories), a much higher level of training will be required.
- *Recruitment*: Managerial staff must determine at an early stage whether to recruit new staff with the necessary skills and experience. If so, they must decide whether the new staff can be recruited locally or whether it will be necessary to look for them elsewhere. In the latter case, it may be appropriate to seek support from foreign sources.
- *Training*: An alternative to external recruitment is the training of existing staff. In some ways, this is more desirable than recruitment, since the staff will already have a thorough knowledge of the work environment. However, technical training alone cannot replace working experience with informatics.
- *Staff retention*: A major problem in the public sector in many countries is the difficulty in creating and maintaining attractive employment conditions, to ensure a reasonable level of staff retention. Very often, greater rewards in the private sector attract informatics personnel out of the health care organization. This usually happens with the more qualified people, precisely those whom it is important to retain. This trend can be very costly, time-consuming and damaging to the public health services. The strategy must take into account the local employment conditions and provide contracts and remuneration packages that ensure satisfactory continuity.

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The strategy should include:

* Outline of the architecture of the systems
* Priorities for applications development
* Distribution of responsibilities and resources
* Assessment and development of human resources
* Rules for protection and security of data
* Standards

2.5.5 Standards

The most obvious rationale for standards is to facilitate the exchange of programs and data. This section describes the areas where standards will be needed and where due consideration must be given to their establishment. Further technical details are contained in Chapter 6.

Data standards

If data are collected by an individual purely for his/her own use, then he/she will define the standards needed for the work. Increasingly, however, data are collected from a number of sources and aggregated at several levels, for further analysis. Computer-based systems pro-

vide enormous benefits in this area. However, one should be aware that standards must be defined and enforced to control the data to be collected, their definition and format, data security and protection, and the medium for presentation of the data.

Technical standards

To ensure compatibility of systems within a nation's health service, there must be technical standards for communication protocols, software packages, programming languages and operating systems.

Work standards

It is almost certain that the strategy will demand some form of sharing or exchange of systems, applications and data between institutions. In these circumstances, it is of great advantage to establish operating standards for the work force. Thus, for example, security and data protection controls should be uniform, in order to permit flexibility of staff assignments and to make sure that the controls are well understood and applied.

Equipment standards

It would be possible to adopt a strategy that demanded absolute compatibility of equipment throughout the service. Effectively, this might mean dealing with only one supplier, with loss of negotiating capability on the part of the buyer. At the other end of the scale, a "do-it-yourself" strategy can be adopted, whereby the buying organizations make their own choices. Such a strategy would be costly and would lead to inefficiency, and is incompatible with the adoption of standards for data management and technical issues. Standards for equipment should lie between these two extremes, and should be carefully thought out, in order to optimize utilization of resources and efficiency of operations.

Training standards

The need for training has been mentioned in section 2.5.4 above. There will be merit in establishing standards of training throughout the service, to ensure predictability of both trainers and trainees.

Professional standards

These are the ethical and technical standards adopted for the informatics professions. They include levels of acceptance of professional behaviour, codes of practice and technical competence for senior informatics staff and management, etc. The strategy should specify the degree of importance given to these standards.

Chapter 3

Informatics Support for Health Programmes

This chapter illustrates the support informatics can give to the management process in health programmes. Specific aspects of the health management information problem are reviewed. Applications for management information systems, decision support systems, modelling and simulation, financial analysis and project management are presented. Examples of resource management information systems, for equipment, facilities, personnel, logistics, finance and information are given. Office automation is considered and prospects for the near future of management support are outlined.

3.1 INTRODUCTION

The basic objective of introducing informatics into health programme management is to improve the quality of information available to managers. This term includes anyone who carries out management functions, and not only those formally designated as managers. Such people constantly face questions of : what to do (uncertainty of action), how (uncertainty of method), how much (uncertainty of demand), when (uncertainty of timing), what to use (uncertainty of resources), and what will happen (uncertainty of results). Reliable information can reduce these uncertainties. With better information, managers will make better decisions leading to improved quality of service and more efficient use of resources throughout the health system.

From the many applications of proven value, a number have been selected for illustration because of their widespread use by many countries and their potential for greater application. The general principles underlying this selection seem to be universally accepted.

Illustrative examples of these applications are given to demonstrate that many are able to provide useful information at several levels: in the first place, to senior government managers and resource allocators; secondly, to intermediate-level managers with responsibility for the control of costs, for the management of institutions or for the allocation of resources to different health care programmes, and finally, to those responsible for the day-to-day management of services or institutions. It will be recognized that, more and more often, applications are being designed to provide information for management at several levels, preferably as a by-product of data originally collected for day-to-day purposes. While such systems are very attractive for higher level management, there are disadvantages as well as advantages. As a general rule the greater the comprehensiveness and potential flexibility, the greater the need for highly skilled technical support.

3.2 THE MANAGERIAL PROCESS IN HEALTH PROGRAMMES

3.2.1 Managerial Concerns

Awareness of the importance of good management and effective planning in the health care field is being stimulated by the increased demand for health care, the ability of the health professions to provide this care, and the limited, perhaps even declining, resources available in the health care sector. Good decisions in resolving the various issues depend on access to good information. The responsibility now placed on the health planner, the health manager, and the health provider is to ensure that the information used is of the highest quality, i.e., that it is relevant, accurate, timely, and in the right format for the purposes at hand. It is the role of informatics to provide such information.

When considering information and informatics, senior managers should carefully review the requirements for data to be collected at the operational level. The choice of the individual items of data when an operational system is introduced will probably determine whether or not the data can be aggregated for use by health planners. Information derived from systems at the operational level will affect not only the allocation of funds, but also the formulation of programmes and consideration of options. The same data, processed differently, will be used for many different purposes. It must be stressed that very accurate data required for day-to-day clinical or administrative decisions, are neither necessary nor affordable for the longer-term decisions taken by managers and planners on more comprehensive issues.

It is fully appreciated that different perspectives can be taken on the assignment of management functions within the health care services. One view considers the management cycle, i.e., different managerial levels are described as emphasizing strategic planning, monitoring and control, or operations. A second perspective has a geographical connotation, describing management by national, regional and local levels. Countries will differ in the number of identifiable management levels. Regardless of which management perspective seems appropriate, the managerial functions require information support. In recognition of the varied situations that exist even within the same country, this chapter deals with the responsibilities and functions of national planning and local implementation. The intermediate (regional) level, where it exists, will often have been performing a managerial function on behalf of the national level. It is of course essential that, where such an intermediate level exists and has been assigned monitoring responsibilities, the information systems are designed to allow this level to perform the task adequately.

While different administrative structures of the health care system can be observed in different countries, the managerial processes for national health development, which involves all levels, should include:

(a) policy formulation and broad programming,

(b) detailed programming and budgeting,

(c) monitoring and control of implementation,

(d) evaluation and reprogramming as necessary.

These processes receive varying emphasis at different levels of management. In determining what type of informatics support is needed at these levels, it is necessary to take into account the types of decision made and the information required to make those decisions.

Policy formulation and broad programming

Decisions made in policy formulation and broad programming deal with long-term objectives, strategies and related targets based on identified priorities and assumptions, intervention strategies, major technology choices, human resources development, methods and level of

funding, organization, and coordination with other sectors. Information required could include: data on population; indicators of health status; environmental and economic profiles; disease trends and patterns; health services utilization; major factors affecting trends and patterns; inventory of available resources and their distribution in the public and private sector; and major policies and activities of other sectors that affect health needs and demands.

Detailed programming and budgeting

The detailed programming and budgeting level of the management hierarchy is primarily concerned with decisions on resource allocation ensuring maximum compliance with the decisions taken at the policy and broad programming level. There is a need for information that permits comparison of anticipated performance with requirements. In other words, the informatics support is provided by systems that permit (for a specific target or related group of targets) testing of alternative activities, their costs and schedules.

Monitoring and control of implementation

At the operational level, decisions are concerned with day-to-day activities. The purpose of monitoring is to ensure compliance with the approved, detailed programme and, if necessary, to initiate corrective action. Here, individual technical actions, expenditures and expendable resource utilization are recorded and monitored. Accounting systems record each transaction: individual staff actions and individual elements of service delivery may be recorded, e.g., by patient and programme. Examples of "technical actions" include immunizations, diagnoses, distribution of drugs, etc. Recording these actions in standard formats will allow the data to be used at this level and to be aggregated for use at higher levels for control and planning purposes. These formats must take account of the fact that data will be recorded in different institutional settings - primary health care centres, clinics, hospitals, etc. Typical examples of systems will include accounting, medical records, drug inventory and distribution, registers of births and deaths, immunization records, equipment maintenance, and personnel registers. More sophisticated systems can provide, for example, information comparing budgets and expenditures; comparisons of achievements with targets; dates of milestone achievements with targeted dates; actual use of personnel by programme function in comparison with planned use; utilization of supplies and equipment with planned use and current inventories.

Evaluation and reprogramming

Evaluation measures the efficiency, effectiveness and impact of the health system to permit a decision as to whether intervention is necessary. Evaluation requires information on the impact of established programmes. Such information may at times have been gathered for other purposes and, at other times, be collected specifically for this purpose. As part of the health for all strategy, indicators have been developed to support evaluation of impact. Use of these indicators will require the collection of information outside the normal control of health authorities. Informatics can support such collection, processing and reporting for evaluation and reprogramming purposes.

No one information system can fulfil all of these requirements. The above examples of information needs show that the variety of management tasks can only be performed well when supported by a "family" of information systems. This family must be conceived as a whole, even if all its members are not acquired at the same time. This will ensure that, as each information system is developed, it is capable of supplying information to levels above, below or alongside. The responsibility for conceiving and developing such a collection of systems and ensuring that the individual systems form part of a well ordered and harmonious whole may be assigned to a

single individual or a team. It is essential that this responsibility is unambiguously defined.

3.2.2 Relevance of the Use of Informatics

Health programmes have much to gain by the appropriate use of informatics technologies. Manual systems of health management suffer from several problems. Foremost among these are inaccuracy and incompleteness. Much strategic decision-making is based on aggregate or derived data. Such data are extracted from primary sources, and, in a manual system, are collected and transcribed by clerical workers. The quality of manually processed data is often suspect. Error rates in data transcription have been studied in several contexts, and mistakes have been found to occur with high frequency. When national strategic decision-making is based on over 1 million separate transactions, the possibility of serious errors in data handling becomes quite significant.

The risk involved in strategic and managerial decision-making is increased when there is no informatics support. The need, for example, to perform "what if" analysis is common to all higher-level decisions, and can often be done only with informatics support.

Another problem in current manual systems is the difficulty inherent in incorporating data from diverse sources or in comparing competing factors. The knowledge base necessary for health care has grown beyond man's capacity to handle it. Determining the relative weight of different information inputs to a health care decision is often not feasible without automated systems.

Problems with manual systems have been noted for some time, but they have recently become critical. First, the sheer volume of health data is increasing exponentially. With the increased volume of data have come different vantage points of interpretation, so that the complexities and trade-offs between viewpoints have increased in parallel. Also, recognition of the impact of fields outside the health sector on

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decisions within the health care environment has escalated in recent years. These current realities are driving demands for rapid methods of managing, maintaining, and aggregating health data.

Information is thus a *sine qua non* of effective health care. It is a key resource. Without informatics, the information needed is often inaccurate, incomplete, unavailable, unreliable, inaccessible, and comes too late to be of value. Furthermore, informatics may be necessary to tap information stored in different files and data bases. At the bottom line, it may be too impractical and costly to collect and process such data without informatics support.

Informatics offers the possibility of improving the collection, validation, storage, retrieval, presentation, and distribution of numerical, graphical, and most recently pictorial data.

Informatics offers managers and practitioners of health programmes the opportunity to improve

significantly the timeliness, accuracy, and availability of the information they need. New sources of data will become accessible through the increasing use of telecommunications systems. Knowledge and literature data bases, which in the past were utilized only by those with direct access, will in the future become widely available.

Informatics offers the ability to store large amounts of data in small spaces. The data are then retrievable with easy-to-use and ever-improving information retrieval systems. Graphical presentation capabilities facilitate the interpretation of large volumes of data. With telematics support, such data can be transmitted and distributed quickly and with little risk of loss. Individuals who previously had to depend on external data-processing groups will be able to conduct their own analyses and display results in the way that best suits their needs.

Informatics and telematics will, if properly utilized, significantly enhance the effectiveness and efficiency of health programmes. Well thought out, coordinated systems have the potential to significantly improve the decisions made in any health care delivery system. With informatics it is possible to design information systems that support day-to-day operations, but that can also automatically aggregate and summarize the data so that they can be used at management control levels. Similarly, data can be further processed and aggregated so as to be of assistance to those involved in strategic planning.

In the fields of management science and operations research, tools have been developed that support the decision-making process. Such tools can assist in choosing among competing alternatives, evaluating the outcome of health decisions, and allocating scarce resources.

These fields can also offer approaches that permit the decision-makers to select the informatics resources themselves. Like any other capital investment, informatics is subject to investment appraisal. The investments to be made in informatics should receive the same analytical treatment that the health agency would apply to other major projects. This should be done formally only when the scale envisioned for informatics use is large enough to justify such treatment. There are, of course, particularities in the nature of investments in informatics, e.g., benefits are often measured in terms of cost avoidance or improved service delivery. Even when a

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INFORMATICS IN THE MANAGEMENT OF HEALTH CARE

* The objective of introducing informatics into health programme management is to improve the quality of the information available.

* Informatics can be used to assist management in policy formulation, planning, budgeting, programme implementation and evaluation.

* Informatics reduces problems of inaccuracy, incompleteness and unavailability of data, transcription errors, and delay that occur in manual management systems.

* Informatics allows the aggregation of data from many sources, the analysis of large volumes of data in a short time, and increased efficiency of collection, validation, storage, retrieval, presentation and distribution of data.

* Informatics can be used to support the managerial routines and the day-to-day operations of health care organizations, contributing to overall efficiency and effectiveness.

formal investment appraisal is not conducted it can still be valuable for managers to use an investment perspective in their decisions regarding informatics use.

3.2.3 State of the Art

Most existing informatics systems support single departments or functions in the health care sector. Several types of systems are available. Systems used to support day-to-day operational actions are frequently called transaction processing systems. A transaction is a routine procedure that generates at least one data item. The output from such systems is primarily directed towards reporting what has happened over a fixed time interval. Refined analysis using such data is minimal.

Examples of operational level systems include accounting packages (e.g., general ledger, accounts payable, payroll), inventory and materials management systems, and personnel systems. Such products are available from vendors, often targeted to specific hardware and software operating systems. Portability and compatibility among such systems are not a high priority among vendors. The state of the art permits the storing of unlimited volumes of data in files, as, for instance, all the basic health statistics on all the inhabitants of a district or on the patients of a health centre. Other examples of operational systems, such as facilities management systems, health statistics data bases, and departmental record keeping systems, are illustrated later in this chapter.

Management information systems

Management control and monitoring systems are concerned with the analysis and interpretation of raw, operational data. Often termed management information systems (MIS), they can be distinguished from transaction systems by the fact that they report on what actually occurred, and compare it with what was expected. Such systems can take data from relevant transaction systems without human transcription.

A standard example of a management information system is a financial management and allocation check system, which operates on data originating from the operational accounting system. Here the manager is interested in summarized financial data, merged with data from another system containing budget statistics, which generates management reports on the expenditures for a given period and identifies the variation from what was expected or budgeted. Many of the currently available systems permit "natural language" queries: "How many of our employees, earning over US$1000 per month, took fewer than five days of vacation in the last six months?" Systems that allow unstructured questioning of an operational data set are known as data base managers.

Other MIS applications involve resource allocation, stock control, analysis of hospital discharges and length of stay of patients, employee productivity and quality indices, quality assurance, and personnel management systems.

Microcomputers and management applications

A wider acceptance and personal involvement of health care managers with computers as planning tools have occurred recently, with the introduction of the personal computer into the office. Managers soon realized the potential of microcomputers for helping them with routine calculations for planning and evaluation. This situation can be attributed to some powerful software packages:

- *spreadsheet programs*, which aid in the construction of double-entry tables of data, fast analysis, reanalysis, simulations, etc.;
- *data base management packages*, which help in the storage and retrieval of information related to planning and evaluation, and provide rapid answers to complicated queries;
- *graphics programs*, which can produce pie charts, histograms, trend curves, etc., that synthesize the outcome of evaluations;

- *trend/statistical* analysis programs, which provide the manager with the extrapolations and forecasting so essential to planning activities;
- *word processing programs*, which help in the production of written reports.

The microcomputer has, in fact, revolutionized managerial work, because it has put relatively powerful information processing tools in the manager's hands, leading to a sharp increase in professional productivity. The linking of micros to mainframes is now extending this revolution, by giving the computer-conscious manager the means to get basic information quickly and directly from the main computer.

Data entry to systems serving all levels of management is currently most often performed by hand. Serious transcription errors occur using this approach. Some financial systems receive input automatically from patient billing and financial systems, whereas some management information systems draw data directly from their relevant operational systems.

Over the last decade, the format of output for health programme management information systems has been improved. Displays can now be numeric or graphic, with colour. Output can also be provided at high speeds through printing devices, or can be transmitted directly to the microcomputer systems of target users.

Uses of telematics are currently rudimentary in health programme management. Although financial and banking data are routinely transmitted electronically, health-related data are ordinarily confined within single institutions. Much more progress has been made in the telematics support of clinical systems (see Chapter 4).

Decision support systems

Systems to support planning and programming are often called decision support systems (DSS). They are characterized by their ability to answer "What if?" questions. To continue with the above example, a DSS to support planning in the area of wages and salaries would permit national health administrators to create scenarios concerning different allocations of salary budgets. Thus, decision support systems can handle questions such as: "What will happen to the programme budget for our primary health care centres if we encourage a policy of early discharge from nursing units in favour of home health care, while all other factors continue at their current rates of change?"

The simplest available DSS is a program that allows the standard arithmetic manipulation of numerical data and permits different display options (see "Spreadsheets" in Section 6.2.2). Higher-level DSS tools exist for decision analysis in specific health care sectors. DSS technology is still evolving, but as organizations store more and more of their data in electronic files and advances in fourth generation computer languages continue, it is expected that this technology will play an increasing role in strategic planning. Other interesting computer-based applications of the DSS type that are useful in the management of health care are:

- *Modelling and simulation*: This is a more complicated form of sensitivity analysis, i.e., testing the results of varying inputs or environments. These terms refer to a more formal activity, where a theoretical management or financial system is simulated, in order to see if certain actions are viable. Simulation and modelling are important tools for planning, because they increase the accuracy and reliability of projections. For example, a manager may want to simulate the queuing of patients accepted for elective hospitalization, as a function of the number of beds, the occupancy turnover, seasonal variation in demand, etc. This will help him to plan for an appropriate expansion/reduction in the number of beds.

- *Decision theory*: A decision-theory approach allows the manager to choose the optimal decision path, when uncertainty is present. It has the same theoretical background as many computer-aided medical diagnosis and therapy systems (see Section 4.6). The manager describes a "tree" giving all the possible paths and outcomes that

can be associated with an administrative project or system, as well as their associated uncertainty factors, probabilities or utility functions. The computer ranks all possible outcomes, and their probabilities of occurrence. For example, a manager wants to analyse the value of installing a new cancer prevention centre, and to select the optimum mix of X-ray equipment. The decision-theory approach can be used to evaluate objectively the advantages, prices and other conditions for each competitive bid.

- *Operations research programs*: These employ optimization methods, such as linear and non-linear programming, minimax and search operators. For example, the manager of a hospital wants to know exactly when the installation of a new surgical room will be necessary. The object is to minimize the financial losses incurred by refusing surgical patients, because of the unavailability of surgical rooms and equipment at any given time, and to maximize the return on investment, at the same time considering the costs of financing. This problem is so complex that it can only be solved by using computers.

Financial analysis systems

The management of financial resources in a health care organization is closely linked to other areas of management (human and material resources, general administration, budgeting, etc.). There are several special application programs and generic software packages for planning and evaluation in this area:

- *Cash flow analysis*: Financial inputs and outputs can be analysed for the purposes of determining seasonal variations, deciding when to borrow money, identifying when critical limits in liabilities are reached, etc.
- *Financial balance analysis*: A relatively simple program or spreadsheet can help in establishing and checking a balance sheet, and in calculating various indices, such as liquidity, inventory turnover, profitability, return on investment, etc.
- *Cost analysis*: The appropriate price for a health care service can be determined by analysing break-even points. For example, the hospital controller wants to know how much the Welfare Department should pay for each bed occupied by a chronic mental health patient, considering all the fixed, variable and semivariable components of cost.
- *Budget planning and control*: Spreadsheets and data base management systems are useful tools for these activities. The manager sets goals, programmes and projects and evaluates how much they will cost, on the basis of surveys and analysis of past data. The projected costs and revenues are allocated among several items. Later, as information about the costs of projects reaches the manager, it can be compared with the budgeted values and, if deviations are detected, corrective action (control) can be initiated.

Project support systems

One of the first applications of computers to the control of complex, time-critical projects used the CPM/PERT technique. (CPM means Critical Path Method, while PERT means Program Evaluation and Review Technique.) Currently, there are many microcomputer programs available for using CPM/PERT methodologies. The only limitation usually lies in the number of events that the program can handle simultaneously, but only rarely will health care projects be so extensive and complex as to rule out microcomputer-based PERT programs.

Both CPM and PERT are time-optimizing methods (i.e., they try to determine the duration of each phase of the project, in order to fix a deadline for its completion). However, there are variants of PERT that can be used for the optimization of the costs, the materials or the human resources to be used in the project.

As the name implies, PERT is also a review and evaluation technique. The constituent events of a project are stored as records of a data base in the microcomputer. Each record contains the name of the event, its preceding and succeeding events, and estimates of time and cost. Each time an event is accomplished, the project manager enters into the record the real costs and time spent.

The computer then recalculates the network, and estimates a new date of completion.

Some computer programs for CPM/PERT analysis are able to draw progress charts (Gantt charts), where the duration of each phase of the project is represented by annotated horizontal bars. The project network (i.e., events represented by labelled boxes, interconnected by 'paths') is also a common output.

Audit support systems

This is another information-intensive area where the microcomputer can be of great help. Periodic audits are carried out to detect irregularities, assess the level of quality of services, the status of human and material resources, etc.

There are several kinds of computer-aided audit. When hospital accounting procedures, for example, are totally integrated into a computerized system, it is difficult to record and store complete data about all the original documents. Thus, the accounting programs have special fields to indicate the nature of the documents, as well as their origin and destination. These are called audit trails. Audit programs are available for different administrative areas: human resources, inventories, acquisitions, accounting, financial management, etc.

3.3 MANAGEMENT OF FACILITIES AND EQUIPMENT

3.3.1 Relevance of Informatics

Management functions related to facilities and equipment within a health organization are complex and numerous. They range from day-to-day responsibilities for maintenance, payment schemes, and plant operation, to the management of minor capital expansion, purchasing, contracts and property and capital development. When an informatics system is being developed facility managers should be asked to describe their tasks and to assist in identifying the part that computers could play in fulfilling those tasks. Informatics offers the opportunity to provide computer support to many of the management functions that are a source of difficulty in many health care organizations. Such functions include:

- selection of potential suppliers

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* Computer applications help the manager to analyse vital information about the organization.
* Transaction processing systems record the basic activities of the organization.
* Management information systems provide:
  - data-base-oriented applications
  - analysis and summary of operational data
  - applications in the areas of resource management, personnel management, operational statistics.
* Decision support systems use:
  - spreadsheets and graphics in microcomputers,
  - data derived from MIS systems,
  - experimentation, simulation ("what-if"),
  - decision-theory approaches,
  - operations research approaches.
* Financial analysis systems use special software and spreadsheets to perform:
  - cash-flow analysis,
  - financial balance,
  - cost analysis,
  - budget planning and control.
* Project support systems include special software for PERT/CPM planning, review and evaluation.
* Audit can be more effective with special support systems.

- preparation of inventories of facilities, equipment, consumables and spares,
- maintenance (preventive and corrective),
- establishment of replacement schedules,
- training,
- preparation of documentation, e.g., manuals,
- contract control,
- financial control and analysis.

All of these functions, separately or together, lend themselves to informatics support. An example is a microcomputer system to provide information support to local managers to assist them in planning for management and maintenance of facilities.

3.3.2 State of the Art

Computer-based systems currently exist that can perform most of the above-mentioned functions. These systems are designed to ensure that the equipment used in hospitals and associated establishments is suitable for its purpose, is maintained in a safe and reliable condition, is understood by its user, and is used with confidence. The systems support management by setting up and updating an inventory of equipment, a formal system of maintenance, and an equipment log containing a history of work done and of equipment reliability. Information on the equipment's history assists in the selection of new equipment by providing details of the overall costs, including labour for maintenance, contract maintenance, spares, and consumables. These systems consist of a set of computer programs which will run on a single user microcomputer configured with a hard disk for data storage.

Computer programs have been developed to address various management functions, as described on the following pages.

Assets management module

The programs in this module allow the storage of detailed technical information about each piece of equipment, plant or building component. Such records are essential to meet health and safety needs, for preparing budgets and plans for replacement of equipment, and in planning maintenance. Recommended spares for any piece of equipment can also be recorded and this, together with the technical information, can assist in maintenance. Requested, planned, and contracted maintenance work can be recorded prior to action being taken, and the system can be used to assist in ensuring maintenance work is scheduled effectively. Job tickets can be produced by the computer and details of all work undertaken can be recorded. Thus a detailed financial and technical history data bank can be produced for each piece of equipment or building element. This data bank can be used for budgetary control purposes, but in addition the information can be used to ensure that assets are neither under nor over-maintained, to monitor plant performance, and to help in formulating a policy.

Stock control module

This provides a basic tool for inventory control of stores. In addition, information about purchase requests and received goods can be recorded.

Energy management module

Energy consumption data for each site can be recorded and compared with predefined targets. Performance reports can be produced.

Renovation module

The computer can be used to store details of each room within a given building, to plan maintenance programmes, and to produce reports.

Budget commitment accounting module

Annual budgets can be generated and stored in the computer, and both commitments and expenditures recorded. Transaction trails, together with various management reports, can be produced.

Annual maintenance plan module

Management can record information on the longer-term planned maintenance and details about minor capital improvements. Various

analyses and management reports can be produced.

Property management module

Basic "estate" information about each site can be stored on the computer and reports produced. A directory of sites can be produced. Additional programs are available to deal with the requirements for residential properties.

Condition appraisal module

This will allow data collected as a result of condition appraisal surveys to be recorded and various analyses and reports produced.

Planned maintenance optimization module

This program calculates the overall costs associated with various frequencies of a planned preventive maintenance task. The user must enter relevant data about the likely costs of breakdowns, planned maintenance work and the reliability of the equipment.

Electromedical equipment management module

This is similar to the assets management module but specific requirements for medical equipment management have been incorporated.

Vehicle management module

This is based on the assets management module but technical data specific to vehicles have been incorporated, as has the ability to plan work on the basis of mileage and other statutory requirements.

3.4 PERSONNEL RECORDS AND INFORMATION SYSTEMS

3.4.1 Relevance of Informatics

Many countries maintain central (national) records of the qualification and subsequent registration (or accreditation) of professional health care staff. This registration process readily lends itself to computer support; large volumes of data need frequent access, updating, and periodic verification. Systems exist to meet these needs, which can be modified to operate according to the laws of a particular country; such systems must usually be programmed at local level.

At local level, specialized personnel departments maintain information about staff. They produce information on, for example, vacant positions, staff assignments, job descriptions, individual personnel data, need for training, job termination patterns, and staff availability. A personnel system, with due respect for requirements of confidentiality, should take into account the fact that the data pertaining to an individual will be of relevance to his/her superiors and should be accessible to them directly. Complex analyses will be the preserve of personnel specialists but the immediate managers should be able to access data about their own staff. The personnel system can be controlled and maintained centrally if the organization so chooses but the staff should have access to the records they are authorized to see. A personnel system can stand alone or be directly linked to budgeting systems and similar strategic planning tools.

3.4.2 State of the Art

The management structure provides a profile of the organization. All the posts have to link together in an ordered manner to provide lines of responsibility and accountability. Computer-assisted personnel systems are able to amend the structure rapidly and provide an up-to-date profile to all authorized users simultaneously, thereby helping management to make organization-wide comparative analysis.

Systems can define the "establishment" of the organization (the preferred number of posts), and keep track of the actual numbers employed against the establishment figure (taking into account full-time equivalents for part-time staff). Quantification of the establishment numbers in money terms is done automatically for estimating departmental budgets.

In many areas of the health service, comprehensive records on staff are held manually by departmental heads. Computerization of these manual systems allows groups of staff to be linked and provides complete, consistent, and comparable sets of data with which to manage the human resources. Computerization of manual records as they stand can provide an electronic filing cabinet for the subgroup holding the records and allows the manager to carry out more flexible analysis of the data.

Through the use of computerized personnel systems, the quantity, quality, and analysis aspects of managing a district can be addressed. These computer systems have built-in security procedures to check the authorization of individuals to carry out the functions they are attempting to execute on the system. Thus, the security and confidentiality of the data can be maintained.

Many personnel systems today are able to answer questions such as:

- Have we any staff currently on duty who speak language *x*?
- Is there anyone with surgical skills of level y who is not on duty but who could be contracted to give extra support today?
- Where is *z* working at present?

If the attendance, absence, and sickness of staff are registered on the system then statistical returns on work patterns can be generated automatically. The personal attendance system can be linked with payroll for purposes of remuneration. By linking personnel activity for each individual through to the payroll process, it will be possible to calculate the "cost" of a particular individual in a specific pay period.

A manager could then get answers to questions for his/her own department such as: how much has overtime for grade *x* cost this month (and how does it differ from other grades or other periods)? Other management issues on an operational level that could be addressed are:

- How many grade *x* staff are there in the district?
- How many staff could benefit from a particular study course and what is the demand for it?
- How many posts and which areas are filled by part-time staff?
- What is the sickness/absence pattern in my department (and is it acceptably near the "norm")?

On a wider scale it may be necessary to consider the ramifications of certain events, e.g., an impending pay award, a move to change the retirement age, a proposed reduction in staff. There may also be a need to investigate local patterns. Is there any change in attendance patterns between summer and winter? Do people appointed from within the district to department *x* progress through the organization any differently from external recruits? Do staff on rotation show greater turnover rates? Similar inquiries could be addressed for all the staff within the organization.

It is not possible to state categorically that all the elements identified above must exist within the human resources system. It is possible for a system to develop in increments or by being linked to other systems. The functions required will depend on the constraints and expectations of the particular organization. Nevertheless, all the functions identified above are almost certain to be carried out within the organization, but local custom and practice will have determined where, by whom, when and how. Consideration must again be given to the data items collected and their definition. Ideally, the data items should conform to the agreed data model which describes the entities and their attributes relative to personnel functions.

Reviews of personnel systems increasingly pinpoint other issues to be addressed. Links can be built between the personnel system and payroll and accounting systems. It is also useful to incorporate any pre-existing systems, e.g., statistical analyses required by central government, within the new system.

In summary, it is necessary to balance the costs of collecting and maintaining up-to-date

data on personnel against the value of having easy access to the data and the opportunity cost of having to collect it on an *ad hoc* basis, should it be required suddenly. Computer technology the tools for handling data in a cost-effective way, but great care must be taken not to hold items or to perform analyses without justification, merely because the technology makes it possible.

3.5 PHARMACY AND DRUG LOGISTICS CONTROL SYSTEMS

3.5.1 Relevance of Informatics

A basic drug information system is one of the most useful applications for computers in health care. It can range from a simple, microcomputer-based system for controlling a hospital pharmacy,

to a full-range, mainframe-based system to control drug acquisition and distribution in a nationwide health system. Depending on requirements and the system's complexity, it may be installed either at national, regional or local level. Another possibility is that several systems can interact with each other in this case, precautions must be taken early to ensure standards of structure, contents and characteristics. The use of computers in the control of drug logistics has many benefits, both from a managerial and from a medical point of view:

- Drug stocks can be maintained at an adequate level, avoiding both excessive tying-up of capital and unforeseen shortages.
- Deadlines for drug validity can be monitored and respected more efficiently, thus avoiding losses due to expiry of effectiveness.
- Computer-based reports about movements and patterns of usage (such as seasonal trends) help in the intelligent management of drug acquisition and stocks.
- Patterns of usage of drugs in the health care system help to establish parameters for new guidelines in prescription, rules for controlling, limiting or expanding areas of usage by health professionals, etc.
- Drug information systems to provide prescribers and dispensers with updated information on drug use, dosages, precautions, side-effects and drug interactions.
- Labels can be printed for individual dispensing.
- Adverse drug reactions and their circumstances can be recorded.

3.5.2 State of the Art

Efficient drug information and pharmacy control systems have been developed for computers of all sizes and types, and are available from software vendors, health care institutions and universities. A typical system for drug logistics control might include several inter-related files, such as a central drug description (master) file, drug package file, stock control files, and vendor/suppliers files.

It is often not necessary to install all files simultaneously. The master drug file must, however, be installed first. Usually, the software does not require users to learn the physical structure of the system, in order to be able to operate it for routine purposes. User-friendly software in this area is usually menu-driven, and data entry can be made on-line, using specially designed forms. These forms can be printed by the computer, and used as data collection forms. The correspondence between the printed forms and the forms displayed by the computer facilitates the data entry.

The drug description master file contains basic data on the drugs used, such as drug identification number, generic name and/or trade mark, dosage form, strength, therapeutic class, dosage level, date of approval for use, etc. Other files, such as one containing descriptions of drug packages, are also needed. This file, for example, includes data such as type of package, number of dosage units per package and price.

In systems where stock control is necessary, a subsidiary file can be created containing information about stock level, last date of entry, order level, minimum acceptable level, etc. This file, as in manually-controlled inventory and stock

control systems, is updated with every stock movement (use and acquisition).

Other assorted files may be used to store accumulated statistics, such as data on treatments given during a defined period. This helps in determining the efficacy of the recommended drugs, dosage and treatment period for the different illnesses.

All the information stored in the system may be used to construct search profiles for information retrieval, such as identifying alternative products for a certain indication, producing lists of available drugs, a price list, statistics and forecasts on the sales and usage of drugs, etc.

The stock control file supports the stock management function. The system can be programmed to produce information automatically on items whose stock level has reached the minimum order level. The forecast function mentioned above can support the calculation of optimum order quantity. Software is also available to support the calculation of order level.

3.6 ADMINISTRATION OF FINANCIAL RESOURCES

Ultimately, all administrative applications converge in the area of financial resources. Pharmacy and payroll, for instance, can be considered as assets or liabilities, and measured in monetary units. Financial resources usually comprise the following areas:

- general accounting
- accounts payable
- accounts receivable
- assets and liabilities
- money management, investments and financing
- cost accounting and budgeting.

Except for the two last items, business computer packages usually have integrated functions, i.e., common files for accounting, payables and receivables, and payroll. The number of transactions per day will usually determine the choice of the most adequate hardware for implementing accounting functions. The limiting factors are mass memory capacity and number of terminals required for data entry.

Accounts receivable is one of the few financial areas that are highly specific for health care organizations. In most countries, there are at least three kinds of patient, depending on who pays for their health care:

- private patients, who pay entirely from their own resources;
- patients paid for by private third parties, e.g., medical insurance companies;
- patients paid for by public and governmental agencies (Welfare Department, National Health Service, etc.).

Accounts receivable systems must keep track of all debts and payments due. Computerized processing of medical insurance forms is widely used, because there are many variants of coverage and norms of billing in countries where private medical insurance is allowed. In North America, for instance, 80% or more of microcomputers sold to private practitioners and clinics are used for processing medical accounts receivable.

Thus, the computer can be used to maintain complex tables of service codes and costs for each insurance company, with billing done automatically, and information about patients and the health services provided to them collected on a daily or weekly basis. The same computer program can keep track of outstanding debts and payments from either private patients or insurance companies, and produce daily, weekly, monthly and annual statistics about the revenues classified by service code, doctor, type of payment, diagnosis, etc. A final benefit of the software package for accounts receivable is that an accurate prediction of income for the next 30 - 120 days can be made.

In countries with government medical insurance, the microcomputer can be very helpful, even in large hospitals, by "mass billing" services, i.e., billing based only on the volume and

types of service provided to insured patients (e.g., the number of operations, X-rays, laboratory tests, etc.). A simple applications program, written in a microcomputer-based Data Base Management System language, will do the job.

Accounts payable, on the other hand, is the administration of payments to third parties (usually external providers of services and goods). Bills must be paid on time for purchases made on a credit basis. Microcomputer-based accounts payable systems are widely available.

3.7 ADMINISTRATION OF INFORMATION RESOURCES

Apart from the specialized information systems used in integrated or stand-alone form in the administrative areas described in the previous sections, health care institutions have many other information resources that can be administered with the help of computers. They can always be characterized as data base management problems:

- ***Hospital statistics.*** Much quantitative data arising from the activities of the health care organization can be produced automatically by computer-based systems. For example, the number of visits, admissions, laboratory tests, surgeries, discharges, and deaths; the length of stay, the productivity of different departments, etc., can be calculated, stored and summarized, with computer help, and may then be used by the hospital manager for planning and control.
- ***Legislation.*** Laws, internal regulations, jurisdiction, etc., can be made available via rapidly searched data bases in order to assist the manager in his/her daily functions.
- ***Document flow.*** The production and distribution of documentation essential to the management of organizations and programmes can be managed using the computer. Documents can be archived and distribution lists maintained for future reference and use.

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* Information systems exist to support resource management functions such as:
  - selection,
  - maintaining inventories,
  - scheduling maintenance,
  - training personnel,
  - stock ordering,
  - contract control,
  - financial analysis.
* Systems can support the management of such resources as:
  - equipment,
  - facilities,
  - personnel,
  - finance,
  - drugs and pharmaceuticals,
  - information.

3.8 OFFICE AUTOMATION

3.8.1 Relevance of Informatics

The organization of the office routine with the help of computers has also reached health care institutions. Organization means the rational division of labour - an appropriate task for computers, which are able, using a number of utility and applications software packages, to provide support to the four main areas of office activity:

- information storage and retrieval,
- organization of time and time-related tasks,
- production of documents,
- exchange of information.

The last of these activities is perhaps the most important one taking place in offices. In conse-

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quence, it has been the focus of many recent products directed at the totally automated office, providing electronic links between people, between people and office equipment, and between devices.

Any kind of office automation, integrated or not, is intended to increase office productivity. However, maximum efficiency seems to ensue when all office activities are based on a common automated system and electronically linked. The office filing cabinet, the typewriter, the copier, the telephone, the microfilm machine, the telex and facsimile machines, etc. all have a common underlying computer-based support. In this way, a computing device on a desk becomes the tool for preparing texts, sending them directly to a printer, to the office manager for review, to a telex machine or through a telephone link to the person who will be receiving it.

3.8.2 State of the Art

Large systems for office automation are based on mainframe or minicomputers and are quite expensive. However, these computers can at the same time be used for other purposes, such as general data processing. In consequence, microcomputer-based office automation is becoming increasingly common in many countries.

In fact, many organizations, which could not support a complex, powerful and expensive integrated system, can achieve savings with microcomputers. Automation of tasks can be implemented gradually, using compatible, standard microcomputers. Later, with proper care in planning, integration can be achieved at a relatively low cost.

Health care management uses tremendous amounts of office labour. Complete records are

written, data are overabundant, filing activities are extensive and all must be maintained for administrative, clinical and legal purposes.

The main applications for computer-based office automation are outlined below:

- ***Word processing.*** This is by far the most common application for computers in the office. Computers can substitute for the typewriter, with many advantages. There are two types of word processor: general purpose computers with word processing software and special purpose computers, dedicated to word processing alone. In the last few years, word processing terminals and clusters (multiuser microcomputers dedicated to word processing) have been rapidly losing ground to stand-alone microcomputers, which are less expensive, can be used for data processing as well, and now have comparable speed and efficiency. If there is a need for interconnection, a local area network can be used. Modern software for office automation includes several powerful word-processing and mailing functions, such as electronic creation and editing of written documents; rapid storage and retrieval of documents from disk; formatting functions (paging, justification, column arrangement, emphasis, setting of font types and sizes, etc.); spelling verification, with a built-in dictionary of 40 000 to 100 000 words; merging functions, which can be used to generate several letters with personalized text, names and addresses, etc.
- ***Information storage and retrieval.*** Filing of names and addresses, folders, documents, correspondence, books and periodicals, etc., can be helped with data base management systems, which are usually very easy to learn to use.
- ***Time management.*** Programs for automating the appointments calendar and for keeping track of individual time allocated to projects, clients, etc.
- ***Telecommunications.*** As well as permitting the sharing of software, data and peripheral hardware (e.g., printers and plotters), a communications facility (i.e., connections via a network and access to telecommunications) allows other applications. Electronic mail, electronic bulletin boards, and teleconferencing are different aspects of the interactive communication capability of computer networks. The local network can also be connected to other computers, through telephone cables, to allow for interoffice communication and access to large data bases (bibliography, electronic publishing, etc.)

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- Office automation has great potential for improving office effectiveness and productivity.
- It can support:
  - document production,
  - information storage and retrieval,
  - time management,
  - communications.

3.9 FUTURE PROSPECTS

The opportunities for development of applications to support improved management are virtually boundless. As an example, consider the management of blood and blood products. This is an exceedingly complex issue which is now further complicated by the emergence of acquired immunodeficiency syndrome (AIDS), and is an area where the use of informatics can have a major impact. Data bases containing the names of donors and their characteristics can provide information according to blood type or place of residence. One could maintain donor histories for all collection stations, to screen for undesirable donors, e.g., carriers of AIDS or hepatitis B virus,

or to prevent over-frequent donations. Systems could provide positive quality control and audit trails for blood products.

Increasingly, computers, computer terminals, and other data collection devices will become available or accessible in health institutions even in peripheral areas. As individual units acquire these instruments data collection can take place throughout the health care sector. This emphasizes the need to establish standards (Section 2.5.5).

If standards are adopted centrally, the formation of networks using telematics will permit the feeding of data "up the line" of the health care system to enhance management control and strategic planning. Thus the health care manager of the future will not require weekly operational reports from the divisions. Rather, the manager will be able to request summary data when needed from several operational systems, in order to formulate timely management reports. These reports will also be available on-line and in a common format, so that the strategic planner can recover the data necessary for entry into a decision support system. These systems will in turn utilize aspects of expert systems technology (see section 6.4), so that the planner's judgement can be automatically imposed on the management data needed.

When the specification for systems is being prepared it is important for the analyst to consider how the information should be presented to future users. The user will often be inexperienced in working with and interpreting columns of numbers, particularly outside his or her own field. Data presentation can be enhanced in MIS and DSS applications through the use of graphics. Graphical output in colour is easier to understand than columns of numbers, and trends are much easier to follow on graphs than by reading numerical output.

Another enhancement will be the incorporation of voice input and natural language processing into operational systems. Currently such systems have a fixed format for data entry, and many MIS uses have to be conceived before the operational systems that underlie them are built. In the future, unstructured raw data will be aggregated into standard formats for operations reports as they are needed.

Telematics is likely to undergo much development and further application to health programme management systems in the near future (see section 6.5). The ability of a network to handle files in parallel will permit automatic data entry from one system into another. Health care managers and planners will be able to communicate electronically, and multi-departmental data analysis will become possible.

Two cautionary notes are needed here. First, these systems are likely to be implemented at different rates in different segments of the health care sector. The planner or manager must be careful to time the development of informatics support carefully, so that technical advances do not greatly precede the ability to exploit them fully. Secondly, although integrated management and strategic information systems are technically feasible and perhaps even affordable today, they require consistent national health informatics policies and standards.

Even if the technology advances along these lines, the key to success is not the technology itself, but an appreciation of what can be expected from informatics among top level health managers and planners.

Chapter 4

Informatics Support in the Provision of Health Care

The contributions that informatics can make to support the provision of self care, primary health care and hospital care are described. Because of their wide use and potential, medical records, literature and knowledge bases, statistics and epidemiology, and clinical decision support systems are discussed in more detail.

4.1 INTRODUCTION

Informatics can be used with advantage to support the provision of health care to individuals in various ways:

- by linking primary health care with the other levels of the health system;
- by providing information to improve the quality of health services available to users at the different levels of the health system; and
- by bridging the gap between knowledge and its use in health care.

When considering introducing informatics into a health care system, it is important that the objectives are clearly stated, in order to ensure that the hardware and software acquired are adequate and appropriate.

This discussion focuses on three levels:

- self and community care;
- ambulatory care (primary health care);
- hospital care (secondary, tertiary and teaching hospitals).

In the following sections the current situation and the future prospects of informatics support are discussed for each level. Medical record and decision support systems, which apply to all levels, are discussed separately in Sections 4.5 and 4.6.

4.2 SELF AND COMMUNITY CARE

4.2.1 Role of Self Care

Self care, i.e., self-delivered health care, represents, on average, more than 70% of health care activities. The importance of integrating self and community care (i.e., from other members of the community) with the more organized, usually state-supported, primary health care has been particularly recognized in developing countries. In these societies, psychosocial, political and economic considerations often force modern medicine to respect the alternative or traditional forms of health care. Self and community care are equally important in industrialized countries, though often in more "sophisticated" forms, such as self-diagnosis and self-medication.

Self and community care can be expected to assume an increasingly important role in the future. These forms of care may improve the quality and extent of health care coverage in

many situations in which distance and/or dispersion of the target population, difficulties in communication, or mere cost may hinder the delivery of organized health care. A main challenge for health care providers will be to convey information on health to the community without disturbing its essential nature or trying to impose foreign ideals and values.

Several important issues must be addressed in order to improve the quality of self and community care:

- the extent and nature of self and community care within the population must be carefully evaluated;
- the people's needs must be assessed and the limitations of self and community care determined;
- appropriate health education and information must be given to individuals and communities;
- some diagnostic, therapeutic and monitoring support should be provided to individuals and communities by the organized health system.

4.2.2 Relevance of Informatics

If appropriately used, informatics can provide highly relevant and cost-effective support to efforts to meet many of these needs. However, while informatics may be a very relevant tool, its effectiveness will depend on many factors, often related to the social, educational and economic level of the population.

The ways informatics can be employed in self and community care closely resemble the ways it is used in the organized health system. Its main uses are: data collection (e.g., history-taking), medical decision-making (e.g., diagnosis), therapeutic action, follow-up and assessment, and maintenance of records.

Informatics can play a role in self and community care in the following areas:

- maintenance of individual and family records, with emphasis on such things as previous diseases, allergies, family antecedents, immunization history, drug usage profiles, etc. Besides offering increased efficiency in record maintenance and retrieval, computers can also be used to notify users of scheduled health care activities (such as immunization of children);
- detection of health risks or significant symptoms, by self-administration of health questionnaires. The computer program, on the basis of data provided by the patient, can recommend preventive actions to be taken, or can refer the patient to organized health care services;
- provision of health information concerning life-styles, sanitation, preventive measures against common diseases, nutrition, first aid in accidents, intoxication, drugs, poisons, epidemics, availability of health care services, etc.;
- provision of health education and self-care training programmes;
- remote consultation and diagnosis: a dialogue between patient and physician can be set up, for example, with the help of electronic mail or videotext. The concept of telemedicine can be extended to include the transmission of biological signals or images through computer networks.

4.2.3 State of the Art

Examples of Applications

The use of informatics in self and community care is still largely unexploited. However, with the increasing influence and availability of personal computers, telecommunications equipment, and general consumer electronics technology, there are now several experimental examples showing the potential usefulness of informatics to self and community care:

- Videotext is being employed to convey health information to the population, through the combined use of telephone and television (see Chapter 6).
- There are software packages for personal computers that provide health information,

health education, and training in elementary health care (first aid, assessment of health risks, etc.).

- Computer network services for the personal computer user also provide environments in which health information, education and training can be conveyed, personal health records kept, etc.

Success in these computer-related or computer-based activities will certainly encourage the development of more comprehensive and effective support systems.

Some Critical Comments

A frequent criticism of informatics for self and community care contexts is that its cost is too high to be justified in poorer countries. It is argued that the widespread use of informatics will require large mainframe computers, reliable telecommunications networks, etc. or alternatively a wide base of personal computers, telephones and modems which at present are available only in the more affluent countries.

While these arguments have some validity, it should be noted that the cost of microcomputer and telecommunications hardware is decreasing rapidly, bringing sophisticated devices within the reach of more and more people.

Strategies for Implementation

There is a multitude of approaches that health care planners and managers can use to implement computer aids to self and community care. These depend, to a large extent, on the choice of the information carrier (videotext, teletext, microcomputer network, etc.).

The use of telematics now appears to be a potentially cost-effective method of providing health information and services in many countries. The cost/benefit ratio depends on the scope, quantity and kind of information and services provided through the telephone network, as well as on the type of information carrier. Coverage of the target population is also very important. The implementation of such self-care support systems will, of course, make use of telematics services already installed and operated for other purposes. One approach is to start cooperative efforts with state or privately owned companies responsible for telematics services. The institutions and/or people to be responsible for the development, maintenance and updating of health information for self care must be defined, contracted, hired, etc. The policies defining access to the system and payment must be defined. Finally, health administrators in charge of the system should plan and implement procedures and standards for quality control, utilization of services, timeliness of information, etc.

Software for microcomputers and computer-controlled instrumentation and audiovisual devices may be developed in special centres set up and operated by health authorities or communities. These production centres have several advantages: costs can be kept low by centralized development and replication, standards are more easily introduced and maintained, quality control is exercised more efficiently. Other sources of interactive information packages for education, training, risk detection, etc. may be software firms, and academic and technical groups. The production of such packages can be certified for quality and approved for use in the same way as are food and drugs. The certification process is extremely important from an ethical point of view, to ensure that the information provided is accurate and useful.

4.2.4 Future Prospects

Technologies that may have a significant impact on self and community care in the future are described briefly below.

Voice synthesis technology

This may be used in conjunction with text-based information systems or in stand-alone form, as a voice-response system connected with telephone equipment. In such a system, the user dials the number of the answering computer and

is prompted by a voice to dial the number of the health information service needed. The answering computer then recites aloud the required information from a computer file. This concept can support practically any computer-based application not requiring images, including consultation of a data base, computer-assisted instruction, remote self-diagnosis, etc.

Optical disk technology

By combining video-recorded images and sound with computers, this technology holds great promise for health education and training.

Artificial intelligence

Assistance to individual patients in resolving self-care problems can be greatly enhanced by artificial intelligence software.

AT-A-GLANCE

* Computers can assist self and community care in:
  - record-keeping
  - detection of risk
  - provision of health information
  - training in self care
  - remote consultation and diagnosis
* Informatics applications in this area are relatively undeveloped at present but show great promise.

4.3 PRIMARY HEALTH AND AMBULATORY CARE

4.3.1 Role of Primary Health Care

Primary health care (PHC) represents more than 70% of all organized health care. Here the majority of primary prevention (e.g., immunization) and secondary prevention (e.g., health screening) takes place. It is here also that patient education (health maintenance, nutrition, prevention of diseases, sanitation, etc.) is most efficient.

It is also at this level that most patients make their first contact with the health system and simple medical conditions are diagnosed and treated. Primary health care has been termed the "entrance door" to a regional and hierarchical health care system. Primary health care is usually responsible for programmes directed to the most common health problems and risk groups and thus must deal with large numbers of individuals. This creates a requirement for systems with massive data storage space, fast retrieval, and cross-linking of data.

4.3.2 Relevance of Informatics

There is an important need for integration of information in at least three directions:

- local integration of information, e.g., a medical information system for practitioners or health care centres;
- vertical integration between primary, secondary and tertiary levels of health care, e.g., in referral/counter-referral of patients to other levels of the health care system;

- horizontal integration of health care with other sectors of the economic and social structure, e.g., welfare, education, work, community organizations.

Computers are useful, and sometimes essential, for mediating this information flow. The use of computers for communication between the various levels can help improve the quality of care.

An evaluation of the performance and benefits of current computer-based systems supporting primary health care indicates that they can help in the achievement of the following goals:

- increased efficiency of operation of all phases of the process of primary health care;
- improved and expedient recording and communication among health professionals through the computerized medical record;
- improved accessibility and timeliness of patient information;
- increase in the quality of health care services provided;
- improved quality assurance of health care;
- improved organizational cost-effectiveness;
- improved epidemiological surveillance, and more reliable health statistics, and performance statistics on the primary care structure.

In primary care, the sequence of action is generally as follows:

- The initial step is data collection. This occurs during the initial interview, and covers the clinical and family history, current complaints, results of the physical examination, laboratory and other tests (X-rays, electrocardiograms, etc.) and other observations.
- Following the initial collection of data, a clinical judgement is made on the diagnosis and prognosis of the current health problems of the patient, and the plan of treatment is decided on. At this point diagnosis may be provisional.
- Action is taken to correct the patient's health problems.
- Following the medical action, any new data obtained are evaluated using essentially the same methods as in the first phase. If necessary, new decisions are made, and treatment reformulated.
- Aggregated data on patients are transferred to a higher level of administration, as necessary for health programme management and planning.

The first and foremost application of computers in this scheme is the automation of patients' clinical records. The medical records system is, traditionally, the hub of all information storage and retrieval, i.e., of patient data, clinical decisions and actions, outcomes and evaluations. Because of the importance of this application, it is discussed separately in Section 4.5.

4.3.3 State of the Art

Despite the progress made as a result of the application of the first computers to the health sciences, it was not until the early 1970s that the first major applications of informatics to primary and ambulatory health care made their debut. Because of their relatively low cost, minicomputers were then used extensively to develop and implement systems for the management of information in hospital-based ambulatory care. The subsequent availability of microcomputers has led to the spread of computer aids to primary health care in developed countries, particularly at the level of private practitioners, group practices, etc. There are now many commercial, privately developed, comprehensive software packages designed to support, in an integrated manner, many of the functions of general practices, such as patient records, billing, scheduling, reporting, etc. These systems are sometimes called the "doctor's office computer".

However, similar progress has not occurred in the area of public health (e.g., in the management of primary health care centres), in part because

the variety of health care services provided with low frequency have inhibited the massive dissemination of computer usage.

The areas of application in primary health care can be divided into two main groups: organizational and clinical. The organizational applications relate to the structural organization of the primary health care sector (already discussed in Chapter 3), and also include some aspects of the evaluation of the outcome of health care.

4.3.4 Future Prospects

When properly used, informatics is a highly relevant and useful tool for supporting information processing requirements in primary and ambulatory health care. However, the way this technology is used will vary according to the country, the health system, and the area of application. Medical records, scheduling, and medical practice management applications exist in great variety in many parts of the world, while the use of computers for medical decision-making, signal processing, therapy control programmes, history-taking, etc., is still rare.

The role of telematics, mainly for computer networks and public services like videotext, will increase its significance in primary health care. Individual health care centres will have greatly increased access to health information and computing services. Timely and accurate reports of epidemiological data, of morbidity statistics, and of utilization of health services, etc. can be greatly facilitated by a network for data collection and pre-processing at primary health care centres. Finally, integration of primary, secondary, and tertiary levels of the health care system is facilitated by computer networks.

Electronic mail is likely to contribute to communication between health personnel working in primary care and those in hospital care. Transmission of images via television would allow primary care personnel to consult specialists in remote hospitals while they are looking at the same patients on the screen. Primary health care personnel in the future will have access to various kinds of information support in their clinical decision-making, such as diagnosis or choice of treatments. This is discussed further in Section 4.6.

AT-A-GLANCE

- Informatics can support primary health care with:
  - a medical information system
  - management of referral
  - medical record data collection and analysis
- Except for "doctor's office" systems, informatics support to primary health care is mostly unexplored.

4.4 HOSPITAL CARE

4.4.1 Relevance of Informatics

Informatics has been applied most extensively at the second and third levels of patient care, namely the hospital level. One reason is that handling of information comprises 25-30% of hospital activities, in terms of cost. Many systems are currently in operation today. However, these systems have different objectives, use various technologies, and have a variety of functions available. Their objectives usually include one or more of the following:

- to satisfy the data processing requirements of individual departments with stand-alone systems, e.g., clinical, laboratory, radiology, dietary, special monitoring;
- to make hospital operation more efficient, by communication of patient data among hospi-

tal departments, processing of individual patient data, scheduling of patients and resources, etc.;

- to support hospital management by providing administrators with timely data, in an appropriate form for their decision-making;
- to provide physicians and allied health personnel with patient data in a timely and appropriate form;
- to provide physicians and allied health personnel with accurate and up-to-date medical information;
- to store information pertaining to medical students and interns;
- to provide specialized disease registers, e.g., for neoplastic, degenerative, or chronic diseases;
- to provide efficient communication with the health-related institutions outside the hospital, such as health centres, outpatient clinics, health administration offices of the local government;
- to provide data for clinical research.

Some of the above objectives are not directly related to provision of personal care. However, as a whole, the system contributes to better care. In Section 4.4.2, the use of informatics in the hospital as a whole will be discussed. Hospital-wide systems are usually called hospital information systems, and may be defined as follows:

- systems that utilize electronic data processing and communication equipment to provide online processing with real-time responses for patient and other related data within the hospital and its outpatient department, including ancillary services such as clinical laboratory, X-ray, pharmacy, etc.

4.4.2 State of the Art

Technological factors

There are several technological issues to be considered for hospital informatics applications. A more detailed description of technologies is given in Chapter 6.

A basic requirement, of course, is to define the type of computer or computers to be used, e.g., mainframe computers, associated or not with mini- and microcomputers, stand-alone minicomputers, or a network of microcomputers. One must also define the types of peripheral equipment that will be used with the system, and the special interfaces that will be required, such as interfaces to automated laboratory equipment, to image-handling devices (video disks, digital radiography, scintillographic cameras, etc.).

The present availability will certainly affect the choice of applications for computers in the hospital, but advanced technologies do not necessarily represent the best solution. Choosing technologies that are most suitable for the objectives in mind, is the key to the success of applications of informatics in hospitals.

There are two functional components of hospital information systems:

- information processing within a department;
- communication between departments.

Departmental Systems

If data processing within a department is a main concern, an independent system is feasible. The advantages of these systems are ease of development and flexibility to users. However, if exchange of data with other departments is necessary, the data must be transferred via paper copy and the system becomes inefficient.

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Such systems are available for:

- patient record-keeping;
- clinical laboratory;
- radiology department;
- medical diagnosis support;
- dietary service;
- emergency service;
- blood bank;
- intensive care unit;
- transportation unit;
- rehabilitation service;
- hospital infection control.

(i) *Patient Record-Keeping System*

Patient data required for medical care, such as name, birth date, physical signs and symptoms, laboratory results, diagnosis, etc., can be stored in a computer. The stored data can be retrieved and transmitted to wherever they are required for clinical purposes. The data can be displayed in tabular or graphic form by the computer for instant assessment of status. The accumulated patient data can also be used for the management and planning of the hospital or, at university hospitals, for clinical research (see Section 4.5).

(ii) *Clinical Laboratory System*

Informatics has been most widely utilized in the clinical laboratory, where a great number of standard clinical tests many of which are now automated, are carried out. This kind of environment is favourable for the use of informatics.

In most clinical laboratory systems, requests from physicians are entered in the computer which is connected to automated laboratory equipment. The results obtained are entered into the same computer, and are often transmitted directly to the physicians. With the use of informatics the efficiency of the laboratory can be increased tremendously. In most hospitals where informatics is used, a clinical laboratory system is an essential component.

(iii) *Radiology Department System*

The radiology department system can be used to control each step in the radiological diagnosis process, to store radiological and nuclear imaging data, and to help personnel to write radiological reports. Since radiological data are image data, the system must also store and retrieve radiographs electronically together with their interpretations. This kind of system is called a Picture Archives and Communication System (PACS). Commercially produced PACS using video disk technology are now available. They permit storage, rapid search and retrieval of digitized images.

(iv) *Medical diagnosis support*

The use of computers to help solve complex diagnostic problems is an obvious application which has received much attention over the years. The use of complicated operations research models (see Section 4.6) and, more recently, expert systems approaches has had measurable success (see Section 4.9.2). The transition from the research institutions to routine use has been slow.

(v) *Dietary Service System*

The preparation of patients' meals requires many calculations, taking into account the variety of foodstuffs, their seasonal availability and the different proportions of nutrients that each patient must take in daily. A variety of systems are available, most of them developed for microcomputers, which provide a time-saving tool for the nutritionist.

(vi) *Emergency Service System*

The demands and volume of many emergency departments, especially those of public hospitals in which the patient, if not admitted, is seen only during the acute episode, suggest that a dedicated system is sufficient. Some specific needs include: possibility to identify unknown patients based on anthropological characteristics; recording of data for medicolegal purposes; statistics of accidents, intoxications and self-inflicted injuries, etc. In many institutions a separate identification number is assigned to these patients and entered in a separate data base.

(vii) *Blood Bank Service*

Some preliminary comments have already been made in Section 3.9. All activities of a blood bank can benefit from automation: maintenance of lists of donors with rare blood groups; control of serological testing of donors; control of frequency of donation and recall scheduling, using computer-generated letters; stock control; recipient identification, including accumulated transfusion control and recording and follow up of transfusional cross-reactions.

(viii) *Intensive Care Unit System*

The specialization of activities and the sophisticated physiological data collection and processing equipment present in these high technology units generate a massive amount of raw data that must be rapidly recorded, interpreted and displayed in view of the critical status of many intensive care unit patients. Dedicated micro- or minicomputers, with or without online connection to monitoring and life-support equipment, are important and sometimes decisive for patient survival. Early computer applications in intensive care have brought rewarding results and have helped establish informatics in the clinical setting.

(ix) *Transplantation Unit System*

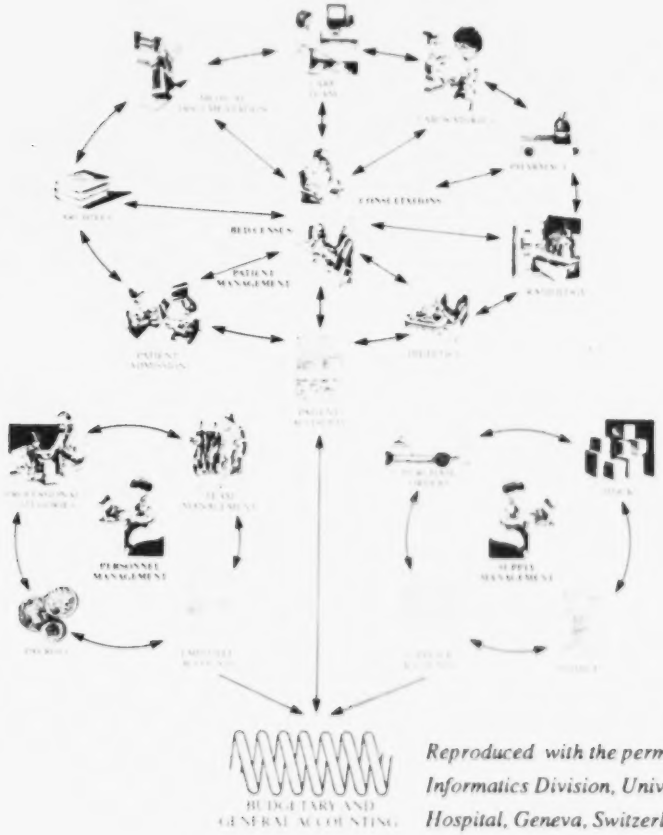
Organ transplantation requires very fast cross-matching of donors and potential recipients. Data from the second group must be readily checked and the best match selected. Practically all transplantation centres today utilize dedicated systems to achieve these goals through the maintenance and frequent updating of immunological and clinical data in data bases that are frequently of international scope.

(x) *Rehabilitation Service System*

In many countries, because of accidents or chronic conditions, the problems associated with continuous care, medicolegal reporting and follow up, and assessment and evaluation of therapy demand informatics support, which can be easily and effectively given by small systems.

(xi) *Hospital Infection Control System*

Clinical data recorded on specially designed forms can be easily combined with data from the bacteriology laboratory to produce reports of interest to the hospital epidemiologist responsible for tracking and control of nosocomial infections. This system can be particularly useful if the patterns of drug utilization are studied in conjunction with the profile of bacterial resistance to antibiotics.



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When other clinical and administrative applications outside the department are integrated in a mini- or mainframe computer, other dimensions can be explored, e.g., diagnosis, treatment procedures, and costs.

Total Hospital Information System

A system that is able to integrate information processing activities in a whole hospital is a total hospital information system (THIS). Sometimes, it is also called an order entry system, because in this type of system all the orders or communications to other departments are transmitted online through the computer. Since the originators of requests in a hospital are often medical personnel, this type of system typically requires medical personnel to operate a computer themselves. This may be difficult, but once achieved, all the important hospital data for patient care as well as hospital management are automatically accumulated in the computer. Once the data are stored electronically, they can be transmitted to remote sites if necessary. Hospital information systems are currently moving in this direction.

Communication Between Hospitals

Once the medical data are in electronic form, they can be transmitted by telephone to any remote site served by telematics. Thus, a group of hospitals can share patient information or medical knowledge data bases. This function can also be used for consultation with experts in other hospitals. The concept can be extended to handle the communication and reporting requirements to public health agencies such as the Ministry of Health.

4.4.3 Future Prospects

Hospital information systems have been a subject of interest to medical information system researchers for a long time, but they are still not at all complete. The objectives listed in Section 4.4.1 are only partly realized in current hospital information systems. The reason most frequently advanced is that the developers of these systems did not fully understand the complexity of a truly integrated hospital information system. They over-estimated the extent to which health care professionals would be willing to cooperate and naively assumed that organizational, hierarchical and interpersonal conflicts would be resolved in a short time, at low cost. Medical knowledge and communication with other medical facilities are rarely included in ordinary hospital information systems. At present, hospital information systems in developed countries mainly address the first four of the objectives listed on pages 39-40. In university hospitals, the use of data for clinical research is also a subject of interest.

Most hospital information systems have been developed on mainframe computers. There has been much speculation that the same functions can be realized by a network of microcomputers using a local area network. Such systems are still experimental, mainly because of the difficulties of managing a distributed data base.

Hospital Information System for the District Level Hospital

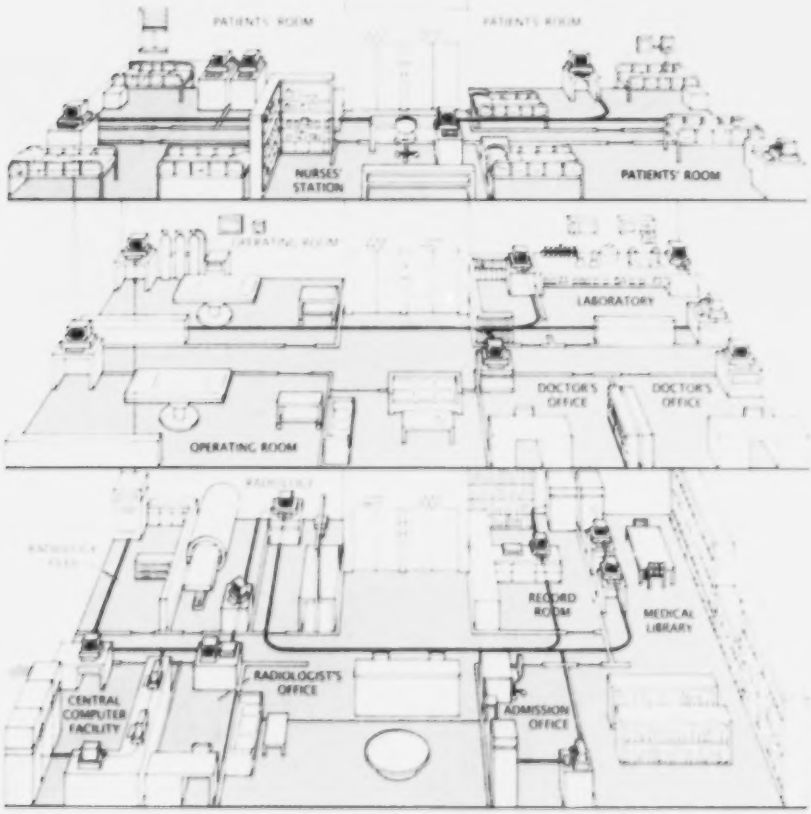
The concept of hospital information systems has been developed in rather large tertiary-level hospitals, which give extensive, specialized care to patients. These hospitals have to deal with complicated, timely data, with extensive communication between the hospital departments.

In this sense, it may be said that the concept of a hospital information system for the district hospital responsible for supporting primary care has not yet been fully investigated. This may be partly because of a lack of national policies. However, this does not mean that information systems for such hospitals are not feasible. Among the objectives of a hospital information system, a patient data base, the supply of updated medical knowledge, efficient communication

with other institutions, and support of management are all feasible for hospitals at the first level.

However, the configuration of the hospital information system in such hospitals will be different from those in the third-level hospitals. The primary care hospitals may not require mainframe computers. Communication between departments may not be as urgent, whereas communications with outside institutions for referral of patients may be more important. Personnel working in the hospital may need more support for decision-making, since they are unlikely to be specialists.

The adaptation of the hospital information system to the local environment is also very important, to provide for prompts, messages and reports written in the local language. Considering these factors, the system architecture in the district hospital may consist of several locally adapted microcomputers connected by communication lines. A computer will store patient data in the district, and it will help plan the curative as



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well as the preventive care. Another microcomputer may deal with stock control and other resource management for the hospital. A third computer may be used for decision support and continued education of the staff of the hospital.

As already mentioned, the components required for the above functions are not yet fully developed in the present hospital information systems. The technologies are now being investigated and are becoming more popular, but various problems remain for future studies.

4.5 MEDICAL RECORDS

4.5.1 Relevance of Informatics

The medical record is the most important tool for information storage and retrieval, and analysis of health care. It is the repository of all information concerning the patient's history and health, diseases, health risks, diagnoses, prognoses, tests and examinations, therapies, follow-up, etc. It is also an important source of information for health managers concerning quality assurance, health statistics, service utilization, and the like.

For these reasons, informatics support of health care is usually centred on the medical record system. While the system is essentially the same at all levels of care, the contents of the medical records stored in the computer may differ at each level. Usually in primary care, in addition to data on medical actions, information on preventive care, such as immunization records, is stored.

Several reasons have been recognized for the use of informatics in medical record-keeping:

- the quality of the medical record is improved (in terms of completeness, legibility, standardization, etc.);
- communication between health care providers contributing to the health care of the same patients is improved, thus continuity of care becomes possible;
- appropriate care and follow-up are facilitated (easy retrieval of information, completeness, logical organization, facilitation of recall, appointments, repeated prescriptions, etc.);
- medical audit may become easier and more accurate;
- clinical research can be facilitated.

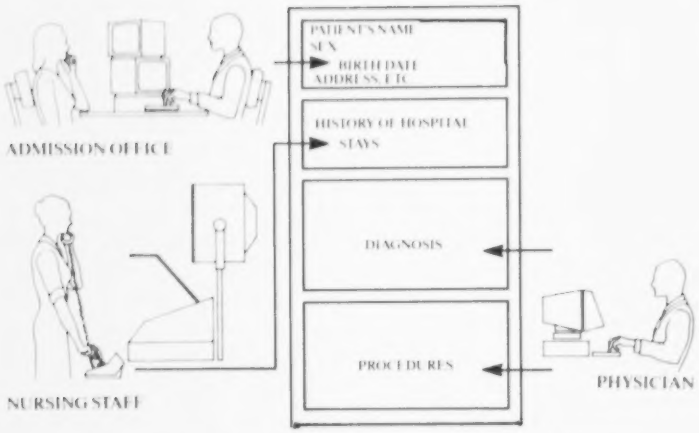
In addition, as a by-product of computerized medical records, national health statistics may be improved in accuracy and timeliness.

AT-A-GLANCE

- Informatics has been widely applied at the hospital level to support:
  - communication between departments,
  - scheduling of resources,
  - patient record data bases,
  - clinical research,
  - data processing for ancillary services.
- Individual computer systems are often used to support individual departments.
- Integrated hospital information systems using the latest technologies show promise.

4.5.2 State of the Art

The medical record can be stored in computers of different capacities, and with a spectrum of detail and complexity. In the simplest application, a microcomputer is used to store basic identification data about the patient, and serves



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as a nosological index for a disease-based recording system. In the most complex application, a complete medical record is kept for each patient.

The majority of computer-based record systems developed so far rely on structured, standardized, codified data organization. A few use natural language processing or unstructured input. The need for a convenient data structure for recording complex medical information has led to the development of more structured medical records, such as the Problem-Oriented Medical Record (POMR). Efforts have also been made to standardize the sets of data stored in a computer. Minimum data sets for hospitalized patients have been proposed.

Other applications relating to medical records include computer-aided history-taking and automated biosignal analysis. In computer-aided history-taking, the computer presents the patient and/or the physician with a sequence of questions, which branch automatically, according to the patient's answers. The resulting data can be stored, listed and analysed automatically for purposes of health screening and referral, classification in health risk groups, etc. Biosignals obtained in clinical tests can be analysed by computer and stored automatically as part of the medical record.

4.5.3 Future Prospects

In the future, new informatics technologies are likely to have a great impact on medical record-keeping systems, and may even change the concept of medical records. Three examples are given below.

Large Data Bases

The medical records of all the inhabitants of a district may be stored in one computer, which may be connected to computers or terminals at all the outpatient clinics and hospitals in the district. Thus, health personnel can have access at any time to the medical record of a given patient. This kind of system is also called a "record linkage" system.

Although such systems are technologically possible, questions of medical and economical feasibility must be solved before they can be implemented. Moreover, protection of the data

contained in such large data bases is a matter of considerable social concern.

Integrated Circuit or Laser Card

An integrated circuit or laser card can hold several megabytes of data and is thus able to store most of the health data on an individual for all of his or her life. Thus, each individual can carry his or her own health record. The technological and economical feasibility of such a system is now under study (see Chapter 6 for technical details).

Optical Disk

The optical disk can store vast quantities of data using a laser for recording and reading in digital form. The characteristic of laser disk storage is very useful for medical records that contain many figures, sketches or image data. Studies to demonstrate the technological and economical feasibility of this new device are progressing rapidly (see Chapter 6).

4.6 DECISION SUPPORT FOR HEALTH WORKERS

4.6.1 Relevance of Informatics

Health personnel at all levels of care have to make decisions when dealing with patients. Diagnosis and choice of treatment are typical examples, but decision-making is necessary at almost every stage of medical action. Computer-based models can usefully capture and support this decision-making process.

4.6.2 State of the Art

There are two types of decision support, namely provision of information and suggestion for action. The first type of system provides health personnel with factual data to help them make decisions, with the decision left entirely to the health personnel. The second type of system provides health personnel with suggestions for decisions concerning the patient in question, on which they can act directly. Although the adoption or rejection of the decision proposed by the computer is left to the user, the information given by the computer can often be very helpful.

Provision of Information

Technologically, this requires an information retrieval system, which may be accessed through telephone lines, or by using mass-memory technologies, such as video disks. Data that can be provided by such a system include drug information, medical textbooks, information to assist in interpretation of laboratory data, or concerning diagnosis and treatment of a certain disease. Such systems are now available in some countries.

Suggestions for Action

With the development of artificial intelligence, computers can now store and process medical knowledge, and use it to draw conclusions on required medical actions. These systems are sometimes called "expert systems" (see Section 4.8 and Chapter 6). Many expert systems have been developed, most of which are applicable in rather specialized fields of medicine. More research, developmental effort and operational demonstration will be necessary before these systems are widely used in clinical settings.

Automatic Interpretation of Biosignal Data or Pattern Recognition

Electrocardiograms are very suitable for analysis by a computer. Automatic interpretation of radiograms may also be possible in certain limited fields. These technologies are particularly useful when large numbers of patients must be dealt with, e.g., in mass screening.

Computer-Aided Health Risk Appraisal

The computer can also be used to help health personnel in medical decisions other than diagnosis. Health risk appraisal by computer is one

such example. The computer uses selected patient data obtained by direct interview, or from the patient's medical record, to classify the patient in special health risk or prognosis groups, e.g., for hypertension, breast cancer, diseases associated with smoking, occupational risk, diabetes, etc. Health professionals and the patients themselves can then be given information for appropriate preventive actions or referral to medical specialists.

4.6.3 Future Prospects

This field has many possibilities, but much remains to be studied. As portable computers become available at lower cost, some decision support systems may be implemented in such computers which may be as small as a hand-held calculator. This storage of appropriate knowledge will help personnel engaged in primary care in the field. These systems will also utilize graphics devices in the future, which will broaden their use by those who have difficulty reading or writing.

4.7 STATISTICS AND EPIDEMIOLOGY

4.7.1 Relevance of Informatics

The statistical analysis of data is an essential element of many activities in health care. The analysis of a large number of cases is often required because of the inherent variability of biological and demographic data.

Statistics are used in the clinical, as well in the managerial aspects of health care. A whole discipline, epidemiology, is based on the statistical analysis of masses of health data. In public health or in the hospital setting, statistical processing is performed constantly. Statistical processing is also used in financial applications, such as forecasting.

Computers have many applications in the statistical analysis of data. Standard software packages are available for most computers, and microcomputer programs, such as spreadsheets and data base management systems, can be used in many tasks of statistical analysis.

Some of the principal sources of data are listed below:

Questionnaires and surveys. These are the most usual means of data collection in the health sciences.

Medical records. The patient's record is used many times as the primary source of information. Computer-assisted statistical analysis is greatly facilitated when the medical records are already stored in machine-readable format, eliminating search, selection and transcription.

Clinical trials. These are experimental or observational investigations providing information on treatment efficacy, effectiveness of screening and other patient management procedures, etc.

Health records. Institution- or population-wide health records, usually found in public health, hospital or population census records, provide the raw material for epidemiological statistics. Analysis of extensive amounts of data is the norm, although rarely as individual patient records.

Clinical laboratory data. Statistical analysis of laboratory data is required for quality control, assessment of laboratory usage and performance, clinical and epidemiological studies, etc.

Biological signals. The statistical analysis of reduced data from physiological recording made in the surgical centre, the intensive care unit, etc., may be performed by computer, in order to provide information about present and past patient health status.

Institutional records. The computer can carry out statistical analysis of workloads, past performance, audits, use of resources, prevalence of health problems, diagnoses, complications, procedures, etc.

4.7.2 State of the Art

How can computers be used for the statistical analysis of data in the health sciences? The answer depends on how much data are to be analysed, and what statistical techniques will be used. The hardware, software and procedures are best specified in advance.

All computers, even small personal computers, can be used to do statistical analysis. In practice, however, there are two key factors:

- *Disk capacity*: Large hard disks can hold enormous amounts of data and are usually very fast. Floppy disks are more limited and slow, but are adequate for most small-scale problems.

- *Data entry*: Data are normally entered into computers through the keyboard for micro- and minicomputers (although card and tape readers do exist), or through video terminals in larger systems (again punched-card based systems are still in existence). This is the most important bottleneck in microcomputer-based statistical analysis. Manual data entry for large quantities of data, or of complex questionnaires and records, takes time. A single-user computer will be in use 99% of the time for data entry, if other alternatives are not used.

Software for statistical analysis

Much good software is now available for carrying out statistical analysis. If very specialized analytical methods are required, some programming may be necessary. The main kinds of software that can be used are listed below:

- *Word processors.* These are used for data entry and correction, mostly when the statistical package requires ASCII data files to work with. A good word processor for this purpose must have a non- document mode, i.e., the ability to produce text files without special marks or codes.

- *Spreadsheet programs* Microcomputer packages can be used to tabulate data and perform simple statistical analysis. They are useful when the number of data records is not too great, and when the software has the more common statistical functions, such as computation of averages, standard deviations, etc.

- *Data base management program.* This kind of package has two benefits: it allows the organization of data as a data base file, with each case as a single record, and it can perform simple statistical analysis. Thus, data are available for retrieval, consultation and analysis. Most data base systems, for example, have internal functions to add, count, average, etc.

- *Graphics packages.* These allow the production of the most common and useful statistical and business graphs, such as line graphs, bar charts, pie charts, etc. Stand-alone packages can retrieve the data for the graphs from files recorded by standard data base management or spreadsheet programs. The graph drawings can be photographed from the screen or produced by graphics printers, plotters, image recorders, etc.

- *Integrated software packages.* These are extremely useful packages for doing statistical analyses, because they integrate several functions in one: data base organization, spreadsheet, chart-making, and sometimes word processing and communication with other computers. By touching single keys on the keyboard, the user can jump easily from one application to another. Integrated packages require large core memories to operate, so that they are available only for 16- or 32-bit microcomputers, and some minicomputers. They are not usually available in larger computers.

- *Statistical software packages.* These are used when more complex statistical techniques are required, such as contingency tables, non-linear models, multivariate statistical analysis, non-parametric tests, etc. There are several types of statistical package for computers which differ mainly in capacity, processing time, output formats, the mode of operation, the way data must be submitted, and the functions available.

- *Epidemiological modelling packages.* Packages are now available that include many of the standard mathematical models used by epidemi-

ologists. These permit the rapid modelling and analysis of problem situations. Some accept data easily from other packages and some emphasize the graphical display of results for ease of interpretation.

4.7.3 Future Prospects

Demographic, sanitary and medical statistics on a population are a very important tool for several branches of the health sciences, such as public health, epidemiology and social and preventive medicine. While, for clinical medicine, the description of disease is always related to an individual, epidemiology and public health always deal with diseases, mortality, etc., in relation to populations. Epidemiology is perhaps the most quantitative branch of the health sciences; the computer is an essential instrument in this field.

Statistics about health and disease are maintained by community agencies responsible for the planning and execution of health care policies and for providing appropriate preventive care, such as immunization. Many developing countries have health care systems based on community principles, but are often unable to collect and process health data efficiently. The computer might be a workable solution for most of the people and institutions desiring statistical data processing.

There are many forms and types of health statistics. Some of them can be easily processed, or at least analysed, in computers. They are related to primary data about the population, such as births, deaths, the incidence and prevalence of diseases and the performance of health care services. In addition to data reduction and description, production of graphs and charts, etc., time series and contingency analysis are important techniques used. Furthermore, several formulas are used to deduce health indicators, such as mortality, morbidity, quality of life or potential years of life lost.

The general principles for the use of general and statistical software packages apply here. Some special applications in epidemiology demand special programs or program packages.

One interesting use of the computer in this area is selective mapping. This technique produces a geographical map, where health or demographic variables are represented in their spatial distributions through the depicted area. Special symbols and/or colours allow the visualization of spatial correlations (with geographical variables, or between spatially distributed variables). Several multivariate statistical methods, such as factor analysis or multiple discriminant analysis, may be used to process spatial data, and to depict the results as spatial distributions. The current graphics packages for computers and specialized peripherals are quite capable of performing such kinds of analysis.

4.8 LITERATURE

4.8.1 Relevance of Informatics

The explosion of biomedical knowledge has compromised the ability of individuals to keep up with new developments and discoveries in health science research and clinical practice. To put things in concrete terms, the first volume of *Index Medicus* (published in 1880) contained about 17 000 citations from 700 periodicals, while in 1986, a volume for a single month had about 21 000 citations from more than 3 000 journals and publications. The raw volume of the United States National Library of Medicine (NLM) collection would require over 4 000 magnetic computer disk storage units to hold it - and this does not include any of the clinical and research laboratory data (images, instrument data, descriptions, etc.) that are generated each year.

There is no other way to organize and structure the information, to store and retrieve it as needed, except with computers. Historically, the biomedical knowledge base has been organized in printed form at five levels, each synthesizing and abstracting the ones below it: raw research or

clinical data, journal articles or research reports, review articles, specialized monographs, and textbooks. This traditional means of organizing knowledge is becoming inadequate, primarily because the growing volume of information threatens to swamp the established library mechanisms. In addition, it is increasingly difficult for investigators to locate and retrieve relevant information from other studies to integrate it with their own work, and for reviews, monographs, and textbooks adequately to capture and synthesize all the knowledge at the underlying levels. Finally, the rapidly changing knowledge base, coupled with the inherent time, effort, and cost involved in updating information in printed media, makes it increasingly difficult to keep the recorded knowledge base current. New approaches are needed to the management of this information. Intelligent retrieval systems will facilitate access to these large data bases and draw from them only the information needed for a particular application.

Rapid access to bibliographical information is another modern requirement, particularly when timely information on the results of medical investigations is needed. Online access, using microcomputers connected as terminals to national and international networks, is another development made possible by informatics.

4.8.2 State of the Art

Computers are being used at several levels of the publishing process in the health sciences. The *Index Medicus*, produced by the National Library of Medicine (NLM) in the USA, is entirely produced and stored in large mainframe computers. The printing of monthly volumes from this material is also entirely managed by computer. Most of the other literature indexes in the field also resort extensively to computers.

This has facilitated the establishment of online data bases, accessible from other computers and terminals, in remote locations, such as libraries, hospitals, research centres, and even doctors' offices, over the telecommunications network spread around the world. MEDLINE is one such service, in use since 1971. It provides online query support from NLM machines and several commercial data base services for literature references from over 3 000 biomedical journals and publications. In addition to text searches, the NLM pioneered the development of a standard set of index terms (Medical Subject Headings - MESH) to facilitate the organization, indexing, and retrieval of the medical literature. The user interfaces for retrieval systems are being improved, by not requiring the user to know the details of the data base organization and allowing queries to be expressed in forms natural to the user.

Internationally the need for access to literature is acute. Developing countries lack adequate libraries, have limited opportunities for training in librarianship, and must depend on field workers who are not fully educated in health professions. Thus, access to remote literature bases is critically important. A telecommunications infrastructure is necessary to support such access.

Other forms of information dissemination are being studied and developed. The editing and dissemination of primary and secondary publications using computers rather than printed material, covers books and periodicals distributed in tape or floppy-disk format, optical disk-based encyclopaedias, and primary publications, such as congress proceedings, distributed through computer networks. Although still experimental, this form of information dissemination holds great promise for the near future, since it considerably speeds the access to primary medical literature, removes the burden of accumulation and retrieval from the libraries, and permits greater flexibility in publication (since it can include image, animation, and sound as well).

Access to large literature data bases using telematics is not the only use of computers in this field. Mini- and microcomputers can be used to store personal or institutional literature data

bases, consisting, for example, of selected or specialized lists of references consulted frequently by the staff, lists of publications provided by the organization, or even copies (downloading) of subsets of MEDLINE and other online data bases. Optical disks attached to microcomputers are showing great promise for supporting these uses. They can store vast quantities of information, which is very rapidly retrievable and is suitable for mass distribution in a read-only format.

Several specialized software packages for libraries can easily implement such literature retrieval services at a local level. They could also be implemented using generalized data base management systems with some programming.

4.8.3 Future prospects

There has been a significant amount of work, largely directed towards meeting the needs of individual institutions or health care environments, on the problems of automating the storage and retrieval of patient medical records. Such systems offer investigators large data bases of patient information with which to conduct prospective as well as retrospective studies. Because they usually represent local information, the studies will be limited until the data bases are linked nationally and internationally providing the foundation for decision support systems with broader scope.

Mini- and microcomputers can be used to store subsets of a larger clinical data base, in order to facilitate statistical analysis of data. These local clinical data bases may be entirely managed by the users themselves, or may be established by copying parts of a larger, central data base. Distributed data bases incorporate this concept of local handling of parts of a larger store of patient data.

More details on this kind of application can be found in Sections 4.5 and 4.7.

AT-A-GLANCE

* A great amount of experience has been gained in the use of informatics for:
  - medical records,
  - decision support to health personnel,
  - health statistics,
  - epidemiology,
  - literature information retrieval.

* These state of the art applications use new technologies such as:
  - laser cards and optical disks,
  - large data base management techniques,
  - advanced decision support analysis,
  - advanced presentation aids,
  - expert systems.

4.9 KNOWLEDGE BASES

4.9.1 Relevance of Informatics

A new application for informatics is the ability to create and update large data bases of knowledge in the health sciences. A knowledge base is different from a literature data base in that it contains medical data organized without specific reference to the literature and includes know-how that has not been formally published. For instance, an international data base contain-

ing the known occurrences of rare congenital malformations is extremely useful for directing international guidelines on their prevention, early detection and treatment, as well as for health professionals seeking information to assist in diagnosis and treatment of individual cases. Clinical research using very large data bases is also facilitated by the existence of such computer-based files. As knowledge bases grow, more intelligent interfaces will help the user locate information from diverse sources and subject headings relevant to research needs.

4.9.2 State of the Art

Guidelines are decision-making models that are explicit expressions of expertise on specific health problems, and are a potential source of a computer knowledge base. In 1984, the *Journal of medical systems* published an article entitled "An expert consultation system for frontline health workers in primary eye care". It described an effort to use a microcomputer-based consultation and advisory system at the primary health care level. The report related how published guidelines developed by an international panel of experts were incorporated into a computer system thus enabling primary health workers to deal with eye problems by treatment or referral. The guidelines consisted of algorithms, flow charts and decision trees that assisted health workers in making a diagnosis and providing appropriate treatment.

The authors developed a prototype reasoning model based on the eye care decision strategy on a mainframe computer and transferred the resulting system for use on microcomputers and hand-held computers in the field. The preliminary testing and refinement of the software were described in the article, which also contained a discussion of the plans for field testing and formal implementation of the system.

This article clearly described the origin of a knowledge base derived from existing, formally stated expert knowledge, and indicated the potential for exploiting the vast amounts of expert knowledge assembled in the form of manuals by making it available to the target audience in an alternative form.

Expert systems are tangible results of research in artificial intelligence and have recently been receiving much attention. A review of the literature reveals a wide variety of knowledge bases and a rapidly evolving technology. Knowledge base systems are finding applications in consultation, monitoring, simulation, providing critiques, tutoring and textual information retrieval systems. A wide range of subject domains treated by these systems have potential relevance to the provision of health services.

The theoretical basis of knowledge base system architecture is under continuous review by researchers and is rapidly evolving in an effort to emulate more reliably human expert performance.

Assuring the validity of a knowledge base system is of crucial importance. As it provides a ready means of technology transfer, care must be taken that it conforms to the indigenous operational environment. The issues of field testing and semantic validity are vital to a successful system.

Interest within the health and medical community in knowledge base systems has grown markedly in recent years. Research has produced development tools that facilitate the construction of these systems; these tools are commercially available and are used by medical experts in collaboration with computer specialists in producing knowledge bases.

Types of knowledge base systems

Knowledge base systems, which have evolved over the past 15 years, employ computers in ways that differ significantly from conventional data processing activities. These systems solve problems or perform tasks that normally require human expertise. Knowledge base

systems emphasize qualitative, logical reasoning rather than quantitative calculations. Logical inference requires logical data. Therefore, the data bases of these systems are predominantly non-numerical, containing symbolic information to represent relationships and dependencies between components. In knowledge base systems, the aim is to represent meaning explicitly by recording concepts in a way that reflects people's understanding of them, but in a form that a computer system can also exploit. One often refers to declarative knowledge and procedural knowledge, the distinction being that, during the inferencing process, procedural knowledge operates on declarative knowledge to produce new declarative knowledge. This process repeats itself in a sequence, or chain, of actions that terminates in a conclusion being rendered by the system. A distinguishing characteristic of knowledge base systems, which is considered below, is the explicit separation of the knowledge that controls the inferencing and the mechanism that performs it.

Within this framework, four broad types of system are found in frequent application in public health settings: (a) consultation systems, (b) critiquing systems, (c) tutoring systems and (d) textual systems.

(a) Consultation Systems

Consultation systems generate advice for the user by using both the system knowledge base and the patient data entered by the physician during the consultation. The system maintains a dynamic data base which provides a continuous record of the current consultation. Consultation systems are concerned with problem solving, usually offering a diagnosis and recommendations for treatment to the user based on the system's interpretation of the user input. These systems are able to account for their actions by justifying their conclusions and by providing reasons as to why they are prompting the user for certain information.

(b) Critiquing Systems

Critiquing systems use a different approach to provide advice to the physician. Instead of trying to tell the user what to do, a critiquing system first asks the physician for a suggestion as to the approach to be adopted for the patient's care. The system then produces a critique, analysing in detail the appropriateness of the suggested approach compared with alternatives. The critiquing system structures its advice around the physician's own thinking and style of practice. It is thought that this approach will prove well suited to domains in which decisions involve a significant amount of subjective judgement, there is no consensus among the experts, or the user exhibits a resistance to accepting recommendations from a consultation system. These systems also have application to teaching.

(c) Tutoring systems

Tutoring systems are derived from an integration of a consultation or critiquing knowledge base and a knowledge base of pedagogical principles and teaching strategies. This concept was developed to exploit the wealth of knowledge in these systems for teaching and to take advantage of their facilities for explanation and justification. Tutoring systems differ from the earlier generation of computer-aided instruction in their representation of both subject material and teaching strategies and the control of the interaction between the computer and the student. This approach offers several advantages: it is possible to record what a student knows, the logic of teaching can be generalized and applied to mul-

tiple problems in different domains, and the model of student knowledge can be inferred from student behaviour and used as a basis for tutoring.

(d) Textual systems

Textual knowledge bases are usually adaptations of knowledge bases found in consultation systems that allow their use as an "electronic textbook". These systems tend to be more general and less focused than, for example, a consultation system; the user may simply browse through the knowledge base with some guidance from the system, without necessarily attempting to solve a particular problem. Other sources of knowledge may be the medical literature and bibliographies that are internally represented and indexed to allow access. These systems find application in diagnosis, treatment and education.

Development of knowledge base systems

In order to illustrate the functioning of knowledge base systems, we enumerate in this section their major components. The operation of a knowledge base system is specified by the manner in which it deals with the following elements:

- knowledge acquisition,
- knowledge representation,
- inferencing,
- uncertainty management and
- explanation.

It was previously stated that a major distinction between the knowledge base approach and traditional systems is the complete separation of the knowledge from the operational aspects of the system. This trait has been exploited by many investigators to interchange different knowledge bases within a specific operational structure. These investigators recognized that as long as the constraints imposed by the knowledge representation scheme of the system are satisfied by the knowledge base, the system should provide a valid environment for deduction. It is therefore possible to (a) move a knowledge base from one environment to another and (b) use a specific environment to analyse or develop different knowledge bases. It is the second of these ideas that gives rise to the concept of a knowledge base system shell.

A shell is essentially an empty knowledge base system, that is, an inferencing environment containing no knowledge. A shell, fortified with screen editors, graphics and other tools, is an environment for development of knowledge systems. A variety of development environments are commercially available for use on mainframes, work stations, and microcomputers. They all deal in some manner with all the aspects of system development discussed below and they can be evaluated according to their efficacy in these areas.

During its development, the system is tested and the knowledge base refined until it gives satisfactory performance. As a general rule, once the development process is completed, the system is finally implemented as a delivery system, written in efficient, operational programming code for operation, on site, on a microcomputer.

(a) Knowledge acquisition

Acquisition of knowledge is the process by which expertise extracted from a person is stated in a formal manner that can be coded in a computer and used in deduction. Formal techniques have been established whereby an expert is interrogated and his or her knowledge captured.

The knowledge acquisition process can be aided by computer. This is particularly relevant during the updating of a knowledge base, when close attention must be given to the consistency and integrity of the knowledge base. New knowledge added or resulting from the modification of existing knowledge may be contradictory, or

redundant in the knowledge base. Many knowledge base system development environments have components that aid knowledge acquisition and maintenance; some are designed to be used by the domain expert without the intervention of a computer specialist.

Induction, or extracting knowledge from data, is another form of automated knowledge acquisition in which a large sample of cases is analysed and symbolic relationships are generated directly from the data.

(b) Knowledge representation

A strong development environment for knowledge base systems will offer many ways for the acquired knowledge in the system to be represented. The most widely used representation forms are: assertions, production rules, objects and frames, and causal networks.

Assertions are descriptive facts, represented symbolically, which are manipulated by production rules and are components of frames and causal networks.

Production rules are composed of antecedent-consequent parts, such that if the conditions defined by the antecedents are satisfied by the assertions resident in the knowledge base, then the consequent portion of the rule is valid and its contribution will be added to the knowledge base.

Objects and frames are used to represent knowledge having an implicit hierarchical structure because they offer the property of inheritance between various levels. Declarative knowledge is often represented by objects and frames.

Research in computer science is devoted to knowledge representation in an attempt to discover and implement ways to represent causal relationships. It has been recognized that rules capture only surface behaviour of experts; it would be desirable to incorporate into medical knowledge bases pathophysiological knowledge to ascertain why certain actions are taken. Causal networks, organized as nodes of information connected by links that specify causal relationships, are under study, and indeed, have been tested in certain systems.

(c) Inferencing

Inferencing is implemented as chaining, that is, the propagation of facts and their use in the creation of new facts in either goal-directed (backward) or data-directed (forward) fashion. Most knowledge base development environments allow for both chaining methods and are called bidirectional or mixed-chaining. This type of inferencing depends on production rules in the sense that forward chaining requires that all rules whose antecedent parts are satisfied be activated. Backward chaining refers to the situation in which an attempt is made to verify a specific conclusion and the inferencing is focused on that conclusion.

Hybrid systems, that is, a mix of production rules and frames, follow a similar inferencing scheme. Purely framed systems perform inferencing by pattern matching in which patterns or structures are compared level by level.

(d) Uncertainty management

Many domains deal with uncertain and ambiguous information. A strong knowledge base development environment will provide facilities for explicit management of uncertainty. Sometimes observations are not made with certainty, but are thought to be valid with a particular degree of confidence. Similarly, the consequences of production rules may not be certain. A frequently used method for expressing uncertainty is by confidence factors which are attached to each assertion in the knowledge base and the consequent portion of production rules. A problem that must be addressed is the propagation of these confidence factors. The knowledge items to which they are attached are constantly reused to

create new assertions by the inferencing process. There are established strategies for determining the confidence of the new assertions.

In another approach, some highly mathematical concepts have been incorporated into some systems to handle uncertainty, namely fuzzy logic and the theory of evidence.

(e) Explanation

Knowledge base systems, in production mode, must be able to explain their reasoning and defend, on demand, their advice to the end user. Basically the types of explanation are: how a decision was made, how a piece of information was used, why a piece of information was not used, why a certain decision was not made, why a certain input was prompted from the user, and the current status of the knowledge base during a consultation. Frequently these explanations are given by a trace of the execution of the consultation. There are, however, systems that require that their production rules have a justification incorporated into them to explain from a domain point of view, why a certain conclusion was drawn.

Knowledge base validation

There are two aspects of knowledge base validation that are relevant to this discussion: the semantic validity of the knowledge base as assessed by experts other than those involved in its creation, and field tests of the performance of the system in its operational environment. In all cases, a clear indication as to whether a knowledge base has been validated, and how the validation was performed, is essential before its use can be contemplated.

(a) Semantic validity

The assessment of semantic validity of a knowledge base may be of particular importance when knowledge bases are acquired from external sources. Committees and consultative scientific groups could serve as validators (or revalidators) of the knowledge. Validity can be tested by performing an experiment in which the system and human experts address identical problems and the agreement rate is evaluated.

(b) Field-testing

Field-testing requires that a knowledge base system be tested within the actual work environment where it is designed to be used. It will be assessed not only in terms of its ability to perform by providing relevant information, but also its ability to be integrated easily into the working conditions and physical environment.

Knowledge bases for tutoring

A natural extension of an operational knowledge base system, and indeed a primary aim in system development, is the use of the knowledge base in teaching. The transformation of a knowledge base for tutoring presents particular problems. Consultation knowledge bases contain no pedagogical knowledge; it is therefore necessary to construct a pedagogical knowledge base and integrate it with the substantive subject matter to be taught. Furthermore, the domain knowledge base is rarely organized in a way that lends itself directly to teaching. A reorganization is therefore necessary to simulate human problem-solving behaviour.

Stages in a knowledge base system life-cycle

In order to provide an indication of the effort needed to develop a knowledge base system and of the attendant commitment of resources, this section summarizes the ideas presented in terms of the stages in the life-cycle of a knowledge base system development project. Although the construction of knowledge base systems is still in its

infancy and no formal methodology has yet emerged, there is agreement concerning the major phases of system development.

(a) Identification of a domain, problem area and operational environment that are amenable to computer-based aids. This point refers both to the applicability of computers to the solution of the problem and to the general acceptance of computer-based solutions by the user community.

(b) The identification, articulation and acquisition of expert knowledge relevant to the chosen problem area. This is the most important facet of knowledge base system development. The interaction between a highly skilled human expert in the problem area and the computer professional responsible for the system development, referred to as a "knowledge engineer", is the most time-consuming element in the life-cycle and its duration will vary according to the scope of the problem.

(c) The encoding of the acquired knowledge into the resident system development environment. With this phase the compatibility of the acquired knowledge to the representation and inferencing possibilities of the development environment becomes obvious. This illustrates the desirability of having many alternative representation schemes available in the resident development environment.

(d) For a limited subproblem, testing of the performance of the knowledge base as a prototype system and refinement as necessary. This step determines the feasibility of further development.

(e) Expansion of the knowledge base to incorporate all facets of the chosen problem. At this point the development process will cycle through steps (b), (c) and (d) in an effort to refine performance and ensure that the knowledge base remains consistent with the addition of new knowledge.

(f) Field-testing of the completed system. The purpose of the field test is to evaluate the performance of the system with respect to: accuracy and reliability of its findings, ease of use and acceptance to users, efficiency of system design, and cost-effectiveness.

(g) Production of a delivery system for practical, real-time use. The delivery system is a totally recoded version; many commercially available development tools provide for immediate delivery of software destined for operation on a microcomputer.

(h) Establishment of a mechanism for knowledge base maintenance as relevant domain knowledge evolves. The implication of continuous maintenance requires an open-ended commitment to repeat stages (b) through (g) to accommodate knowledge base updates.

An important aspect is the rapid development and changing nature of knowledge which will affect the maintenance of the knowledge base. Some of these changes will emerge from results of clinical research. A significant portion of new knowledge will also be derived through evaluation of programmes in specific operating environments. In all fields and disciplines a challenge in maintaining the relevance of any given knowl-edge base is posed. Moreover, technologies that support these knowledge bases are subject to evolution.

Experience to date indicates that the development costs of knowledge base systems exceed those of more traditional informatics applications. The engagement of domain experts and specialized computer personnel for lengthy periods is often cited as a cause for elevated costs. The tendency, however, is towards rapidly de-

clining development costs as a result of technological advances that have reduced the time required by expensive personnel.

AT-A-GLANCE

* Knowledge base systems are receiving intensive research effort
* The state-of-the-art permits practical applications
* Development of practical systems is costly and time-consuming,
* The potential pay-off from use of knowledge base systems appears great.

4.9.3 Future Prospects

One of the principal impediments to the implementation of primary health care is the lack of relevant and accessible technical and managerial information. In addition to information based on analysis of statistical or quantitative data, there is another area of information that has potential significance in health care delivery, i.e., the body of qualitative expert knowledge related to a defined health problem or technology and to the cumulative knowledge acquired through experience. This need for qualitative information has been widely recognized. Expert knowledge is made available through the dissemination of publications, but more effective means must be found to make this information readily accessible to those who provide health care.

The recent emergence of expert systems to support knowledge bases in health and medicine may well provide the technology to make available relevant knowledge bases that can be used by health workers in an appropriate manner and at a time and in a place where they are required. These technologies should be used in a way that contributes to the overall effectiveness of the health system, as well as provide relevant support essential for both basic and continuing education in health programmes. The development, maintenance and effective use of knowledge base systems in the health services, as well as their support implications, must, however, be further explored. This can only be achieved through practical experience with the application of these systems in institutions, programmes and services where they can be effectively used.

Chapter 5

Informatics for Health Manpower Development

Informatics requires specialized manpower for its proper use. This chapter reviews the need and the training programmes required to fulfil the need for general as well as specialized training. Informatics also shows great potential for computer-assisted instruction, computer-assisted learning and computer-aided management of the education process.

5.1 INTRODUCTION

Information is a vital factor for socioeconomic development, and human resources are a critical ingredient in this process. Informatics links information to the human user. It requires specialists to develop the links and informed users to take advantage of them.

This chapter addresses the requirements for manpower development for health informatics specialists as well as for health care personnel who need training in the use of computers. Emphasis is given to the training of the health informatics specialist. The chapter also addresses the problem of using informatics as an auxiliary tool in education and training. The third section identifies means of educating and upgrading existing health care personnel. The fourth section discusses the types of health informatics specialists required and presents the ideal characteristics of the most senior informatics specialist in an organization.

The second major discussion topic of this chapter is computer use in training. The chapter concludes with a short review of the potential use of informatics for health manpower development in general terms as part of the education and training process.

Throughout this chapter, the term "organization" is frequently used. It is intended to refer to any health care organization, a health care delivery system, a regional organization, a hospital, a clinic, or even a department. The basic principles apply to all.

5.2 THE NEED FOR QUALIFIED INFORMATICS PERSONNEL

The development of sophisticated clinical and management information systems requires individuals who have been trained to communicate and work with people of varying backgrounds and skills; to manage information resources; to utilize modern computing and communications technology effectively; and to appreciate the complex dynamics in health care. Successful implementation of a computer-based information system is as much a social process as it is a technical one. Specialists are required who have an organizational and management focus as well as a machine or technical orientation.

Existing technically oriented programs in computer science focus on improving the ways in which machines process data. Information science is more concerned with using information to make decisions. Health information science is particularly interested in the unique decision-making requirements of professionals and managers working in health care delivery settings. Practical experience has emphasized the

need for health informatics specialists to be familiar with the concepts, problems and methodology of medicine, the structure of the health care delivery system and the complex problems pertaining to system design and integration in that environment.

5.3 MEANS OF TRAINING EXISTING HEALTH CARE PERSONNEL

5.3.1 Introduction

A wide array of methods and materials are available to educate health care personnel in the use of information technology. The time spent in "education" can be justified on the basis of the expected quantitative and qualitative benefits. An organizational training programme in informatics is necessary. As concluded earlier, the fate of the organization in the future will rest on how well it "manages its information".

Many questions arise associated with the spread of "computer literacy". How should it be carried out? What should be taught? Are existing educational and training programmes relevant and efficient?

Guides on how to teach the teachers are readily available. One such guide is the WHO Offset Publication No.35, "Educational Handbook for Health Personnel". This handbook provides a framework to develop a training programme. In any training programme the most critical step is to define one's educational objectives. The educational objectives of a health informatics programme will vary depending on the personnel for whom the programme is designed - physicians, nurses or others. Specific objectives for health informatics specialists are discussed in Section 5.5.

The development of a health information system and the introduction of informatics technologies in a health system introduces major changes in a complex and large organization. Such innovations usually have a qualitative impact on the way health work is done. This impact is often reflected in major shifts in the roles and functions of health workers. For this reason, the active and continuing involvement of health care personnel in the development and implementation of information systems is essential. Such a participation requires appropriate orientation and training.

5.3.2 Formulation

A training programme on health information management should be based on an overall informatics strategy for the organization. A programme for training existing health care personnel should derive its requirements from the user component of the information systems development strategy. Therefore, the aim of the training programme would be to develop self-reliance of health workers in the use of informatics technologies related to their work responsibilities. Given the large number of training activities which could be provided for existing health care personnel, there is a need to develop a framework for the training programme. The framework should reflect the essential needs of the organization and the health care personnel and provide a basis for all training activities in this field. It could be developed around the following activities:

- learning activities intended to familiarize staff members with the potential and utility of existing informatics technologies and trends and developments in the field;
- training activities such as workshops, seminars or courses aimed at developing skills in how to use microcomputers and standard software packages; and
- educational activities that focus on the knowledge and experience needed for developing and managing an "information centre" for an organization, such as a health centre, a hospital or a programme, a project or a unit.

On the basis of the needs, the training objectives and the framework for the training programme, training activities can be designed for specific user groups such as health centre

managers, nursing supervisors, hospital administrators, and directors of programmes. This approach not only improves the effectiveness and facilitates the selection of relevant training materials and presentations, but also simplifies the process of implementing and evaluating the training activities.

The training programme should thus resolve issues such as: the desired qualitative and quantitative skills of the human resources; the levels of cognitive, affective and psychomotor skills to be achieved; relationship to the external job market (hiring vs. brain drain); and teaching methods to be used. Resolving these issues will be controlled by the availability of funding, educational environment, curricula and instructors.

In designing the programme it must be remembered that the health informatics programme is not an end in itself. It is a powerful tool to enable health personnel to perform their functions more effectively. This view will guide the structure of the training programme.

Among the basic goals of the training programme which should be achieved at all levels and for all professionals are the development of :

- positive attitudes towards informatics;
- technical knowledge to use informatics properly in their own jobs;
- realistic expectations regarding informatics;
- capability to make appropriate decisions regarding selection and use of applications.

5.3.3 Implementing a Training Programme

A health organization which is planning to introduce informatics will make a considerable investment in preparing its users. In addition, enthusiasm is often generated as users become more familiar and comfortable with the technology. Any training programme must be viewed at the onset as an evolving set of training activities which are upgraded to meet the changing needs of the health workers in the long term. These factors have a significant bearing on the decision for selecting the resources for implementing the training programme.

There are essentially three options to be considered:

- to develop and support a full-time teaching staff of a few individuals who could subsequently be complemented by a network of trained users within the organization;
- to engage individuals on contractual services to design, implement and evaluate training activities using the resources of the organization;
- to use the facilities and resources of the private or commercial sector for designing and conducting the training.

A mix of the three options may be considered.

Health personnel vary greatly in both their educational background and their educational and training needs. Analysis of these needs is the initial step for curricula development. In this analysis one should consider whether the user is an informatics specialist, potential project initiator, routine user or occasional user.

The teaching mechanism should be adapted to the specific needs. Among the multiple possibilities are :

- introductory courses oriented toward the mass transfer of knowledge and skills;
- specialized programmes for specific user groups (physicians, nurses, home visitors, etc.);
- general programmes as part of professional qualification;
- postgraduate courses for specialists.

5.3.4 Selecting Software Applications and Developing Training Materials

To be effective, training material should closely approximate, if not simulate, the actual data, analytical and decision-making process at the health worker's level of job responsibility. This permits the person being trained to concentrate on developing the necessary skills to use the computer and its software by exploring its capabilities through manipulating familiar information.

Developing training materials can be costly and time-consuming or relatively simple, de-

pending upon the level of sophistication desired. Initial training needs would probably be directed at raising the level of awareness of the health workers being trained. As such, simple examples could be developed. As training objectives evolve toward the development of more sophisticated skills and knowledge, more complex materials such as case studies and simulation models may have to be considered.

5.3.5 The Selection and Training of Trainers

There are a number of sources from which trainers for informatics can be obtained. The training divisions or programmes of most health organizations are staffed with qualified trainers. Universities have departments or institutes which specialize in management training and related fields. Private or commercial organizations often have training staff, particularly for informatics. However, it is very likely that training staff assigned to long-term training programmes in informatics in health will require specialized training.

A trainer in informatics in the health field should have:

- interpersonal skills, particularly the ability to manage groups and support individual and group problem-solving activities;
- knowledge of informatics technologies, particularly practical operations;
- knowledge of non-formal educational techniques, particularly for the design and evaluation of training activities and for the management of training programmes;
- knowledge of health care and public health management concepts and practice.

5.3.6 Continuing Education

The avenues to continuing education are many. The traditional methods of reading and research are well known and well developed. A growing number of books and publications are

available which introduce health care personnel to varying aspects of computing technology. *Medical Informatics, Methods of Information in Medicine*, the *Journal of Medical Systems*, and *Computers in Health Care* are examples of journals entirely devoted to the application of computing technology in medicine and health care.

5.3.7 National and International Associations

In many countries, a national health informatics association provides a forum for the exchange of ideas, concepts, and developments. Their primary objectives are to disseminate information on applications or approaches through such media as seminars, workshops, conferences, and newsletters, thereby providing various sectors of the health care system with a source of information and expertise. At the international level the International Medical Informatics Association (IMIA) is an aggregate of national societies and interest groups. Another type of professional organization which can be of help in disseminating knowledge to users is the medical (general or specialized) association. These associations often organize workshops on specific topics of interest. These non-profit organizations might organize, develop and deliver workshops suited to the needs, interests, and timetable of practising health care personnel.

5.3.8 University Programmes

Another means for training existing health care personnel is university or technical school courses. These programmes prepare individuals to synthesize principles and concepts of health care delivery, health data and information, information systems, computing technology and human behaviour. In particular, students are taught to appreciate the respective roles of patients, physicians, health care professionals, institutions, government, and others in the creation, handling and dissemination of health information. The students are given a sound foundation in information systems and technology and their application to organizational problems within health care. Some of the courses are also taken by practising health care professionals by correspondence, in intensive one- or two-week sessions, or via telecommunications.

5.3.9 Distance Education

Distance education is one of the most exciting new developments. In many countries, networks are being established to integrate the efforts of universities, colleges, provincial institutes, school districts, government ministries, and provincial agencies in the development and delivery of educational programmes. Multiple levels of service are already in place, including: interconnected university communication systems; interinstitutional instructional networks which are being used for specific groups of people; educational TV channels to deliver educational programmes into homes via satellite and cable systems.

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- The specialized skills of a health informatics expert should be available to the organization.
- Every organization should have a training programme oriented towards its needs and reflecting the background of its existing staff.
- A variety of training mechanisms is available to satisfy the training needs.

5.4 TYPES OF QUALIFIED HEALTH INFORMATICS PERSONNEL

5.4.1 Introduction

The personnel required in the field of health informatics range from data entry operators to a chief information officer. These personnel are to be found in all public sector segments of the health care system, including:

- hospitals, extended care, and specialized facilities;
- allied health care organizations such as workers compensation, cancer control, Red Cross, etc.;
- government departments and agencies such as ministries of health, social services, computing corporations;
- health care associations.

In these environments they occupy positions in computing services, administration, research, health planning, quality assurance, management, engineering and laboratories. They hold titles such as systems analysts, programmers, programmer-analysts and research assistants.

In the private sector, health informatics professionals are found in:

- physicians' clinics and offices;
- private laboratories;
- management consulting firms;
- software houses;
- computer hardware firms;
- manufacturing and production industries (occupational health);
- insurance companies;
- pharmaceutical companies.

Here they are involved in various applications such as collecting and analysing health data, designing and implementing systems, or marketing and support functions.

5.4.2 Occupations

There are, as yet, no industry-wide standards for positions related to "informatics" in health care organizations. The larger hospitals and government agencies, however, are beginning to develop specializations.

Programmers exist in most groups associated with computer-based information systems but are generally involved in implementation, not analysis, design, and utilization. Programmers tend to come from computer science training programmes.

The title "analyst" or "systems analyst" is used for individuals whose work is more people- or organization-oriented than computer- or technology-oriented. Work of this type requires a good understanding of both functions as well as above-average interpersonal and communication skills. An analyst is often expected to be an interface between the two cultures of the organization environment and the technology environment. People in such positions are ordinarily oriented towards achieving managerial status.

Other positions are emerging as information systems become increasingly integrated into private and public organization structures. Titles such as "data base administrator" and "security and control officer" describe responsible positions associated with specialized areas of an on-going information systems activity.

Perhaps the most important staff member dealing with informatics in any organization is the one commonly known as the chief information officer.

5.4.3 The Need for a Chief Information Officer

The "manager" of corporate informatics, or chief information officer, has evolved over the past 30 years from being a superclerk/broker who reported to the accounting area and whose educa-

tion was high-school mathematics to a change agent who reports to the highest executive level and whose education is typically at the Master's level.

Perhaps in no other organizational function must such a broad amount of knowledge be tapped to manage properly. The field of management information has a variety of rapidly changing technologies such as computer hardware, software, and data communications. One has to keep up on specific managerial tasks, e.g., systems development methodologies, project management systems and charging mechanisms, as well as general managerial tasks associated with leadership, organizational change and implementation procedures. Finally, because of the decision-supporting function, there must be an awareness of quantitative processes and procedures.

The health of an organization depends to a large extent on how well its members generate and use information. The manager who is to coordinate the acquisition and provision of information must understand how people process information, both as individuals and as members of organized groups or units. If an organization adopts a "corporate" view to its information, then it is important that the informatics service and its staff report at an appropriate level. The control and utilization of information will cross divisional and departmental boundaries. The generators and providers of information, if they are to be effective and objective, must be removed from divisional or departmental "interests".

5.4.4 Functions of the Chief Information Officer

Although responsibilities may vary somewhat, based on the organization's size, the following functions tend to apply in most cases:

- to develop effective planning processes for aligning all information systems services to the structure of the organization;
- to integrate effectively the functions of administrative, clinical, and financial information and telecommunications support;
- to determine the investment to be made in information systems and to provide a rigorous and disciplined framework for evaluating information benefits versus information costs in achieving the organization's goals;
- to anticipate and understand the economic and organizational consequences of introducing new information technology;
- to explain and teach information systems technology to staff at all levels of the organization;
- to utilize qualified outside expertise on an advisory basis;
- to establish and implement a long-range information systems plan which is consistent with the organization's objective and direction;
- to plan and coordinate all information systems within the organization, including computing services, all minicomputers and microcomputers, office automation, management engineering, voice communication and other related areas;
- to provide consulting services relative to information systems for the organization;
- to develop policies and procedures to ensure that: (1) requests for personal computers, terminals, office automation devices, and various software packages are justified and coordinated; (2) the information systems plan is followed; and (3) the return on investment for all areas of information systems is maximized;
- to staff the information system operating areas with competent and innovative personnel;
- to establish specific standards and guidelines for the definition, measurement, use and disposition of information so that the entire organization is operating within the same framework;

- to coordinate the development of the necessary tools to manage the data resources, e.g., an organization-wide information directory and a data-element directory.

5.5 CURRICULA IN HEALTH INFORMATICS

5.5.1 Introduction

The design of a curriculum is often constrained by the need to build on courses already in existence at a university or technical school. As a programme develops and becomes established, courses specifically tailored to requirements in the field of health may be introduced.

Original programme planning should draw heavily on the experiences of others. From a health and medical perspective, the work of Reichertz, Mohr and their German colleagues should be carefully studied. The curricula of graduate programmes in the United States should also be evaluated. From an informatics point of view, the recent Association for Computing Machinery (ACM) document entitled "Information Systems Curriculum Recommendations for the 80's for Graduate and Undergraduate Programs" makes clear the difference between information systems and computer science.

The ACM proposal recognizes that information systems concepts and processes are taught within two contexts: management knowledge and technical information systems knowledge. Computer science on the other hand, tends to be taught within an environment of mathematics, algorithms, and engineering technology.

An informatics specialist is expected to work within the environment of an organization and to interact with both organizational functions and computer technology. A computer science specialist has less interaction with organizational functions and more interaction with hardware and software technology.

5.5.2 Suggested Curricula

To satisfy the multidisciplinary needs discussed above, the subject areas to be taught can be classified into three broad categories, separating three interrelated disciplines:

- health informatics, which is concerned with the methods and technologies of computing;
- health development, which addresses concepts, methods and technologies related to health care; and
- managerial processes for national health development, which consists of the collective approaches and methods for improving the efficiency and effectiveness of health care organizations.

Annex 2 contains sample curricula.

5.6 USING COMPUTERS IN TRAINING AND EDUCATION

5.6.1 Relevance of Informatics

The utilization of computers in training and education is not novel. Practical use started with the introduction of the first time-shared mainframe computers in the 1960s. However, computer-assisted and computer-based education has increased exponentially in the last decade, with the appearance of inexpensive but powerful microcomputers. Many experiments around the world have demonstrated that education in the health sciences can benefit in several ways from the utilization of computers. Computers allow an increase in the efficiency of the learning process, while reducing its costs:

- ***increased efficiency*** is achieved through interactive, performance- oriented, individualized learning; through an increase in student motivation, and through the implementation of advanced instructional strategies which

would be impossible for mass education without the help of computers (e.g., simulation, interactive remote education);
- ***cost reduction*** is achieved through a reduction in the time taken to reach instructional objectives, a diminished dependence on highly specialized instructors, the asynchronous utilization of material resources by students, and the possibility of faster updating of teaching materials.

5.6.2 State of the Art

There are four main types of applications of computers to education: (i) computer-assisted instruction (CAI), (ii) simulation, (iii) computer-assisted learning (CAL), and (iv) computer-assisted management (CAM).

Computer-assisted instruction

This is the most common application of computers to education in general, but it is not widely adopted for medical education. There are several forms of computer-assisted instruction (CAI), but the predominant form has been the so-called *tutorial*. A tutorial is a kind of "interactive book", whereby the computer presents teaching material to the student, interspersed with exercises and tests. According to the results of the tests, or the student's desire, the CAI program will branch out to other segments of the teaching material. The interactive organization allows for individual, unassisted instruction, which progresses at the student's own pace.

Tutorials have the same general objective as didactic textbooks. CAI can be greatly effective for some areas of instruction, but is quite expensive to develop. In order to facilitate the development of CAI lessons, a number of tools and special languages have been developed. Teachers with restricted experience with computers, who do not wish to learn programming, can produce CAI lessons ("courseware") with the help of application packages called *authoring systems*.

Simulation

Computer-based simulation is a very rich and resourceful way of complementing teaching activities. Using a video terminal or a microcomputer, the student can interact with dynamic and complex mathematical or symbolic models (such as models of physiological systems or economic models), and conduct "experiments" with them by systematically changing their parameters, etc. The computer is practically indispensable in the majority of biological simulations, because the underlying mathematical models are very complex and usually unsolvable by common mathematical techniques. Furthermore, sophisticated resources like dynamic charts and animated pictorials, interactive simulation, etc. greatly increase the pedagogical value of simulation programs.

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- A wide range of technical specialties, including a chief information officer, contribute to a health informatics unit.
- Formal degree-granting programmes in health informatics are offered at the university level.

Another way of using computers is to teach students how to build their own models, and how to simulate them in the computer. In this way, health science students will learn more about the scientific facts and methods, increasing the soundness of their knowledge. Simulation and modelling can complement laboratory work, and can be coupled with CAI programs.

Computer-assisted learning

This category is different from the previous applications of computers to education, because here the computer is a learning tool which is used by the students themselves, rather than a tool used by teachers to assist instruction. Typical examples of this kind of application are:

- programs for consultation and calculations in the areas of medical diagnosis and therapy;
- generic software packages that help the student to follow the courses, to prepare term papers and laboratory or clinical reports, draw charts, etc.;
- access to online data bases for bibliographical references, reading material, remote courses, etc.
- computer programming and operation.

Computer-assisted management

This name designates the applications of computers to the organization and management of the educational process. Here, the computer can be useful in many respects:

- the planning and implementation of educational structures and activities;
- the design of courses, teaching materials, class schedules, organization of curricula, class outlines, etc.
- the evaluation of student performance, the automation of academic records (marks, class frequency, etc.).

Chapter 6

The Choice of Informatics Technology

This chapter reviews some of the considerations for selecting the hardware and software for use in health informatics applications. The many criteria which influence the selection are listed. Some of the common systems issues are discussed with emphasis on the need for standards. Some of the current technologies available for informatics and telematics are described. Some cost considerations are reviewed.

6.1 INTRODUCTION

The previous chapters have highlighted the pivotal role that information plays in the operation and management of contemporary health services. This chapter is intended to introduce some of the essential features concerning the technology which should be understood at decision-making levels, especially decisions on the most adequate technology to use for health applications, the evaluation of cost and benefit, the role that future technologies may play in this area, etc.

The following sections of this chapter examine several key facets of technology that can influence decisions relating to health informatics in both developed and developing countries.

6.1.1 Selection of Computers

The introduction of computers for information processing in a health care organization must be preceded by a careful and thorough process of planning, specification and selection. Depending on the goals and the scope of automation which are desired for the institution, this process may comprise the following steps:

- analysis of information processing goals and needs;
- specification of hardware, software and services;
- selection of computing hardware;
- selection of operating and utility software;
- selection of applications software;
- selection of subsidiary services (for example, teleprocessing);
- planning for implementation, training and support.

These steps do not follow each other in a linear fashion, but are highly interactive and interdependent. The planning/selection steps are repeated several times, until all the requirements and solutions coalesce into a coherent, acceptable picture.

The time and effort necessary to complete the planning/selection/acquisition cycle will be quite different from one application to another. It may take a few days, for example, for a simple

solution involving the selection of a portable computer to be used for scientific calculations; or several months, when the goal is the automation of a complex hospital.

This section reviews several of the factors which are involved in the selection of computer hardware and software for managerial and clinical applications in health care.

6.1.2 General Criteria

The most basic factors to be followed for systems selection are:

- ***Reliability***: hardware and software should not fail frequently, and easy correction and/or recovery should be possible (i.e., maintainability);
- ***Compatibility***: they should be compatible with other lines of standardized hardware and software;
- ***Capability***: a general term encompassing overall central and mass memory capacity, processing speed, throughput, hardware and software resources, etc. The kinds of applications, the size of files and the speed of access, the need for special interfaces or converters, etc., determine what capability is required;
- ***Expandability***: the possibility of complementing the hardware and software, by adding new modules, peripherals, expansions or resources, without the need to change the existing configuration. In operating, utility and applications software, this property is called *upward compatibility*.

Other general factors to be considered in the selection process will have variable importance, according to the kinds of users and of usage considered:

- ***Ease of training and of use***: This is an important factor in all settings, but its importance will be greatly increased when hardware and software are to be used directly by health care personnel who have neither inclination nor time to undergo costly and long periods of training.
- ***Vendor support***: The responsibility of the vendor or supplier of hardware and software does not end when these are delivered and paid for. The complex and failure-prone nature of such products demands a reasonable assurance of technical support to the user in the forms of: correction of programming errors, replacement by new releases, technical information, contracts for maintenance and repairs, etc. The best software and hardware products have all these modalities of support to the user, including warranties of a reasonable duration. However, promising support is not enough: it is very important to evaluate the vendor's reputation and assurance of continuity.
- ***Rate of obsolescence***: This has also a relative importance in the context of health care applications. It is advantageous sometimes to buy the latest innovations in hardware and software, in order to postpone as long as possible the problems caused by obsolete computers and peripherals disappearing from the market; it is also true that selected hardware/software combinations remain useful for long periods of time, regardless of the existence of more sophisticated solutions. Concerning technical obsolescence caused by continuous advance, an adequate remedy is to choose equipment and programs which can be expanded in the field at a low cost.
- ***Viability vs. flexibility***: The success of a hardware/software combination is closely related to the flexibility of the solution provided by it (or, better expressed, by the proximity to the user's needs and by the adherence to existing manual procedures). The least disciplined solution is to build a computer system by combining hardware from several origins, and to develop from scratch all the applications programs needed. This is also the least viable solution, because many subsystems never work together as desired. The most rigid solution, on the other hand, is to acquire a *turnkey system*, i.e., a hardware/software

combination providing all aspects of the desired automation goals and functions. It also may be the least flexible solution, if the design forces the user to adapt procedures to the computer's and not the opposite. The latest-generation computer software and hardware, however, have done much to circumvent this problem by providing solutions that are, at the same time, flexible and viable (for example, database management systems that can be programmed easily by the user).

- ***Security and confidentiality***: The need for these controls is particularly pressing for medical database applications, and for teleprocessing systems. Usually, security of data, programs and operations is provided either by the operating system or by the applications software. Older versions of microcomputer operating systems may not provide sufficient protection against unauthorized copying, deletion and access to disk files.
- ***Transition to other systems***: This is the answer to the question: what will happen when I change the computer, or when I change the software? These changes can be easy or they can be extremely difficult, or even impossible. This is also an important selection factor when a new computer is under consideration. Since the problem of transition almost surely will have to be dealt with in the future of any computer installation, it is better to choose hardware and software which will facilitate it.

We have not considered the strategic considerations in the selection of technologies, which were treated in a sufficient level of detail in preceding chapters (see Chapter 2). We discuss now the issue of setting technological standards.

6.2 SYSTEMS ISSUES

6.2.1 Existing Computer Architectures

Until the 1970s a single choice of computer system architecture was possible: the *mainframe*. This centred on a large central processing unit (CPU) connected to mass storage and input/output devices. Early health care systems were built using mainframes, and for many applications they are still preferred. They have immense data storage capacity, can be easily maintained and controlled, and have the virtue of centralizing data storage and output. Modern patient care information systems and many financial and administrative systems are based on mainframes.

In the 1970s a breed of computer was developed which is less powerful than a mainframe but has the capability of supporting a wide variety of departmental applications. This, the *minicomputer*, is the most widely used machine in health care. A group of minicomputers, connected to a network, can achieve the data-processing power of a mainframe and offer increased flexibility. In fact, minicomputers do not need to be from a single vendor; current systems development is actively pursuing connectivity between different makers and models of minicomputers. For a health care environment that needs decentralized data handling, or where different data-processing tasks have different levels of complexity, a minicomputer network may be most advantageous.

In the late 1970s smaller *microcomputers* became available; these are the dominant tools of the 1980s. A microcomputer is generally designed for a single user. For health care, micro-

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- It is important to follow a systematic methodology in the selection of informatics hardware, software and services.
- Criteria to be considered include reliability, compatibility, capability, and expandability.
- Other key factors are ease of training, vendor support, obsolescence, flexibility, security and conversion.

computers find applications in research, as interfaces for laboratory instruments, and as personal productivity tools. Microcomputers can also be networked, although they cannot, as yet, perform large data-processing tasks. Finally, microcomputer performance is already reaching that of smaller minicomputers, and multi-user microcomputer systems are increasingly common.

Different information needs require different system architectures. Although the state of the art limits smooth intercommunication amongst systems of different sizes at present, this will pose less of a problem in the future.

6.2.2 Standardization

The importance of standards has been emphasized in Chapter 2. This chapter focuses on technology-related standards.

Standards are formulated to allow maximum use of the same set of programs and data. This does not, however, imply that a single hardware configuration must be replicated at all sites involved in health informatics. It is feasible to use different hardware from one vendor, or from several different vendors, provided that the same software, such as the operating system and key programs, can be used.

However, many hardware systems claiming to be fully compatible with some popular model turn out to be only 99% compatible. Making changes in 1% of the codes frequently turns out to be a difficult task. To mitigate this problem, it is essential to exercise due caution while adopting standards.

Areas Requiring Standardization

It is useful to think of standards at three distinct levels. First, in terms of standardization of data or information. Second, in terms of the computational facilities required to manipulate and store the information. And third, in terms of telecommunication facilities employed to transfer information between two or more geographically dispersed sites. These three levels of standardization are discussed in the succeeding paragraphs.

Standards for Information

Information consists of data of many different types, including symptoms, treatment, funds, patient records, personnel records of health workers, etc. Such data are generated at the individual level and the institutional level. The basic data are subsequently filtered, consolidated and used at the national level. For the data to be easily exchanged and aggregated, it is essential that all data-generating centres use a common standard for *data input* and *internal representation* in the computer.

In order to permit data to be stored in a compact manner, and also to achieve faster storage and retrieval speeds, the raw data must be encoded. For example, instead of using the full name of a district, use of a 3-digit code enables better utilization of memory space as well as faster response from the computer. Obviously, for *codes* to be useful, it is necessary to establish a unified coding scheme.

An example of an *information standard* of general interest is a data dictionary. A dictionary can contain definitions for thousands of data items and entities of organization-wide interest. A second dictionary can exist for the microcomputer environment. By adopting common data element structures and definitions and validation rules, such as financial allotment number, geographic codes, etc., the same information can be readily used for different applications, even when different models or makes of computers are used. The International Classification of Diseases is a coding scheme familiar to health professionals.

Standards for Computing Facilities

The term "computing facilities" encompasses both hardware and software. *Hardware standards* refer to the make and the model of different types of computers - mainframes, minicomputers, and microcomputers. *Software standards*

relate to operating systems, programming languages, and application packages.

Hardware Standards

The choice of hardware standards must take into account such issues as local manufacture, staffing requirements, maintenance, and the availability of an adequate range of off-the-shelf software to run on the hardware selected. Based on the amount of data involved, the nature of processing to be performed, the likely number of users, and the geographic location of the users, one can opt either for a centralized mainframe approach, a decentralized minicomputer or microcomputer approach, or a hybrid.

Apart from the main processing unit, one requires peripheral devices, including display devices, printer units, secondary storage units, etc. It is desirable to establish guidelines for procurement of such hardware. Acquisition of too many diverse types leads to subsequent problems in terms of lack of replaceability among devices and a need for larger numbers of spare parts. On the other hand, if all items are procured from a single company, the country becomes dependent on the sole source. It is therefore preferable to standardize on a type of product rather than on a particular make.

Software Standards

Although the hardware of a computer ultimately determines its capacity for storing and processing information, the user seldom has occasion to deal with the hardware directly. A hierarchy of programs, which together constitute the software of the computer, intervenes between the user and the hardware. The part of the software that is most closely associated with the hardware is the *operating system.*

Application programs are the ones that ultimately determine how effective a computer is in meeting human needs. Because of the high cost of software development, it is preferable to invest in off-the-shelf *application packages.* These packages fall into two categories. The first category consists of software oriented towards a specific task or operation, such as a payroll system or an inventory system. Such packages are discussed further in Sections 6.3 to 6.5.

The second category of application packages consists of a set of tools that can be used for many different applications. Some major types of application packages are:

- *Spreadsheet packages* which are used in applications involving numerical information. Such applications involve addition, subtraction, and other mathematical operations on numbers arranged in tables. Financial and statistical applications are often of this type. This category of application is often the first taken up for processing on computers.
- *Word processing packages* are used for applications involving textual information. Such applications involve editing of text and printing of reports and letters.
- *Data base management packages* enable information to be stored and retrieved in an efficient manner. Such packages also enable subsets of the information base to be printed in a systematic manner.
- *Graphics packages* are used for applications involving graphics/pictorial information. Pictures, in general, convey more information than pages of text. Also, the value of pictorial information is independent of languages and local customs. Some graphics packages are designed for preparing graphs and plots, while others are oriented towards drawing pictures and generating presentations. It is now feasible to perform both types of activities using a single package.
- *Statistical packages* are used for storing, analysing and summarizing raw data, and for detecting trends and correlation patterns.
- *Bibliographic packages* are used for storing bibliographies and for retrieving information or references based on a set of keywords or phrases specified by the user.

The above list illustrates the diverse range of user needs served by various generic application

packages. Each package requires a considerable investment of user time in order to be used efficiently, and most packages cannot interchange data easily. Hence it is worthwhile for the organization to standardize on certain packages.

Standards for Telecommunications Facilities

Unlike the early years of the computer era when stand-alone applications dominated, the need to transmit and receive data and programs is an important characteristic of the current generation of systems. The computers may be located within the same office building or separated by long distances. Processing may involve a simple exchange of messages or full-scale computing with input and output from and to any location. The processing may be batch or interactive, and the communication line may be:

- a point-to-point connection by ordinary cable within the same building;
- a point-to-point connection through a leased line or public telephone line;
- a connection through the nodes of a commercial international communication network;
- a single channel line (base band); or
- a multi-channel line (broad band) capable of carrying voice, data text and video signals.

Those intending to use electronic communication techniques for exchanging information must decide on the type of communication link, the choice of terminal equipment, and the type of modem to be used to interface the terminal equipment to the communication links. Unfortunately, in many of these areas, standards are still at an evolutionary stage. International agencies and bodies are involved in this continuing endeavour including the International Telegraph and Telephone Consultative Committee (CCITT) of the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO). The standards most relevant to the needs of the health sector are discussed below.

Choice of Telecommunication Link

Digital information can be transmitted over existing telephone networks, both land-based and via satellite. In each case, a single voice channel is used to transfer digital information. The use of telephone links is good for slow-speed, sporadic transmissions; however, the error rate is relatively high. In a *dial-up network*, the user has the flexibility of accessing multiple points alternately through the call set-up process. The charge in such networks is almost always for time used.

The second common method is to use a packet switched network. In such a network, a long message is split into a set of *packets* of a predetermined size, and these packets are transmitted. The charge is based either on the number of packets or the total number of characters transmitted. While packet switched networks offer great communication capacity, they also involve higher initial investment than dial-up networks.

To the extent that countries and regions start developing their own public data networks (PDNs) and that these PDNs start being interconnected, PDNs will constitute an excellent support for data transmission and communication among various units of a given system and among different systems. A PDN is a service (based on a protocol known as X.25) provided usually by the telephone and telegraph company of a given country, or even, in some cases, by a company especially created to supply data communication/transmission facilities, and consists of data channels interconnecting basically an entire country or region. These channels can be initially accessed, often at a little more than the cost of a local telephone call, and once this takes place all the computers connected to the network can, from a technical point of view, also be accessed. (From an operational and a legal point of view, permission has to be required, password given, instructions relayed, etc., for a computer to access another.) In many cases, this may provide a more efficient and cost-effective way for computers to

communicate with one another than direct, private lines or even dialled lines. Besides the cost of the telephone call necessary to connect to a PDN, there are, of course, charges based on the duration of the connection and on the number of packets/characters transmitted.

Choice of Terminal Equipment

The teletypewriter is an example of terminal equipment. However, during the 1980s, *display* (i.e., mostly video) terminals have become predominant. The operation of the video display unit and its peripherals is controlled by a terminal controller, which frequently is integrated into the same chassis as the display. The current trend is to use a microcomputer as a terminal. In addition to its use for accessing and downloading information from the main host computer or data base, the microcomputer can also be used to do local computing, and is often cheaper than a stand-alone "intelligent" computer terminal.

The newer generation of terminals support lower case as well as upper case characters. Thus, they can be used for text processing applications. Use of local language character sets is also permitted in some cases. In *graphics terminals*, display of graphic and pictorial information, side by side with text material, is permitted. Colour display units may be preferable to monochrome displays for some applications.

Current technology also offers a wide array of portable and pocket terminals. These are usually hand-held or lap-size microcomputers, which can be used as remote, online or offline data collection terminals. Many models incorporate interfaces and/or modems, permitting direct connection of the terminal to a larger computer, through cables or telephone lines.

Choice of Modems

A *modem* is used to convert digit signals from the terminal into a form compatible for transmission on an analog telecommunication line. A modem is specified in terms of three characteristics:

(i) *Speed*

The effective speed of transferring information is governed by the transmission line, the terminal equipment, and the modem. Most terminals can support different transmission speeds. Higher speeds imply superior transmission lines and better modems. However, a lower speed modem can be used on a high-speed line.

(ii) *Synchronization*

To permit the receiving terminal to decipher one character from another in the data stream, two alternative techniques are employed. In *asynchronous* transmissions, the sending terminal adds start-and-stop-bits to each character. These bits are used by the receiving terminal. In *synchronous* transmissions, no identifying bits are used, and the modem must supply timing information to enable the receiving terminal to identify the beginning and the end of each character.

(iii) *Mode*

In full duplex (FDX) systems, transmission can occur simultaneously in both directions. In half duplex (HDX) systems, only one direction is permitted at a time. In many modems, the setting can be easily changed from one mode to the other.

6.3 HARDWARE

In an institutional environment, the conventional arrangement has been a mainframe system to perform all computations. The data are entered and retrieved using terminals located in the offices of doctors, nurses, and in the laboratories. These terminals are now being replaced by microcomputers. Instead of using low bandwidth telephone lines, intelligent local area networks

are being used to integrate information stored in two or more different computers. In addition to the physical point-to-point communication, an intelligent Local Area Network (LAN) provides the following added services:

- multi-point logical connection for equipment in the network;
- protocol conversion to enable equipment of different standards to communicate;
- communication traffic control (securing, routing, logging, etc.);
- resource sharing (hardware, software and data); and
- systems software support for distributed application system development.

Based on the above advantages, one current trend is to design institutional information systems using a number of minicomputers and microcomputers interconnected by a LAN. In such a LAN, a peripheral attached to one computer can be shared by other computers connected to the network. Contemporary LANs make it feasible to readily share information, hardware, and software resources. Also, they can be used to access information from other data bases via appropriate communication links.

In the near future single-user workstations will become available that consist of (1) a bit-mapped graphics display of at least one million pixels, necessary for sharp image projection, (2) at least one megabyte (MB) of main, random-access memory, and (3) a processing speed of at least one million instructions per second (MIPs). Widespread availability of these machines will enable the development of the "physician's workstation", a personal computer capable of literature retrieval, chart making, basic image and signal processing (e.g., ECGs), and basic decision support (i.e., at the level of today's medical expert systems).

The 1990s will see revolutions in mass storage capability. The contemporary microcomputer

can store upwards of 100 million characters (100 megabytes) of data. A total hospital information system requires in the order of 1 megabyte of storage per patient. Hospital mainframes ordinarily require many gigabytes of storage; these machines are currently sold with 10 gigabytes, or more, of high-density disk storage.

The power of a health care information system is heavily dependent on the amount of storage space available. A larger memory space implies storage of more information and knowledge. Ideally, one requires a very large, but inexpensive, memory technology. Also, to prevent accidental or deliberate erasure or modification of the information, it is preferable that the storage media be immune to power failures or tampering. At the same time, there should be a facility to enable additional information to be recorded using low-cost equipment. All these desirable characteristics are met by the *write-once optical disks*. These disks offer large storage capacities, typically 500 megabytes or more, at a relatively low cost. The disks have long life and the recorded information is relatively immune to magnetic or other physical disturbances. Information in each storage cell can be recorded once, and once only, using optical disk drives. Over time, more and more storage cells will be recorded. However, the content of a recorded cell cannot be altered using current technology. The optical disk offers adequate storage space for an incredible amount of health information. When the individual moves to a new health facility, he or she could present the optical disk to familiarize the authorities with a full medical history.

Also, small plastic cards are now coming into use, which can store several megabytes of information. These cards have different mechanisms to store data and are called "IC cards" or "laser cards". They can store part of an individual's health record. The cards are likely to have a great impact on health record keeping in the future.

6.4 SOFTWARE

The development of improved methodologies for designing, implementing, and verifying large software systems is essential. For systems of the scale relevant to biomedicine and public health, formal methods of program generation and correctness verification will most likely be increasingly used in the coming years. Current research focuses on the programme development process itself as a knowledge-based activity. This requires expert systems to help manage large software systems. By the year 2000 (or even earlier), automatic control of software systems will be on the horizon.

Higher-level languages will improve over the next 15 years. New languages will centre on the human-machine communication, interpreting natural language input, and the encoding of problem-solving activities. System software developments will focus on the provision of a more convenient and intelligent user interface to computing resources, remote graphical access to medical information systems, and efficient concurrent and distributed processing among parallel and workstation processors.

In the microcomputing environment trends suggest standardization around two well developed operating systems: MS-DOS and UNIX and their derivatives. This greatly facilitates the usability of standard and context-specific application packages, and should decrease the time required for transferring applications from system to system.

Applications software development will become progressively slower and more complex. As the user base matures, the health care worker will come to demand more performance from software tools. Already the development costs of software exceed that of hardware; this will be magnified in the future. A possible window of opportunity exists for developing countries

in the area of applications software development. Labour costs are a fraction of those in developed countries, and applications software development is a time-intensive occupation. Such opportunity suggests a role for national health ministries in acquiring a fleet of moderately priced workstations for applications software research and development, perhaps in partnership with local university computer science departments.

Areas of applications software research in the next two decades are plentiful. Among those considered most fundable are:

- ***Knowledge representation***. The expression of medical information in mathematical and symbolic form has always been critical to the health professions. Fundamental research is needed, as well as the development of a global, unified, medical language system.
- ***Knowledge acquisition***. Research is needed in automating and updating the construction of knowledge bases. Related research is needed in the construction and maintenance of archives of raw data.
- ***Medical decision-making***. Algorithms, decision analyses, and expert systems are some of the most popular applications of medical informatics. Research is needed in the design, validation, and evaluation of these decision support tools.
- ***Human-machine interface***. Medical information systems require an interaction between a computer system and a health professional. Between these two very different information processors is a tricky, technically vague, interface. Interface research focuses on natural language and speech processing, speech synthesis, real-time graphical image analysis, and system-to-system communication.
- ***Information storage and retrieval.*** The United States National Library of Medicine estimates that its existing collections comprise approximately 2.15×10^{12} characters and that the collection is increasing by about 34% per year. Electronic publishing will increase this amount sharply in the next years, and pressure is now being applied to include images, instrument data, and patient information into the information base of medicine. Research is needed in bridging obsolete and modern information storage technologies, automated classification of reports and journal articles, and new ways of indexing medical data so as to support application-specific inquiries.

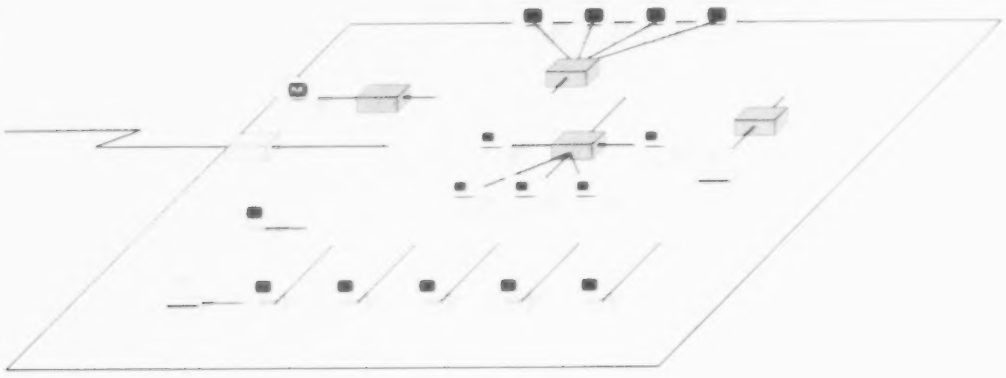
6.5 COMMUNICATIONS

Some other new technologies have relevance to the health sector.

6.5.1 Large and Distributed Data Bases

Various international, national, and private organizations have collaborated to gather huge amounts of information and to establish large data bases. The term "data base" was originally coined to denote a reservoir of numerical information. Now, data bases contain textual information and even pictorial information.

Facilities are provided to enable direct access to the designated subset of information. By entering a set of keywords with appropriate operators (e.g., AND, OR conditions), it is possible to access the set of desired information. Some of these data bases also provide references to documents, journals, and articles containing additional information about a particular subject. Such *referral services* significantly reduce the amount of research time required to locate the source of information. Further, algorithms have been developed and incorporated that allow for intelligent searching of the information base. Because of these additional features, such aggregates of information complemented by built-in decision rules are termed *knowledge bases* (see Section 4.9). Knowledge bases now exist for a range of topics including disease identification, vaccine development, and antidotes for poisons.



6.5.2 Networking and Telecommunications

The growing population of microcomputers does not imply that microcomputers will eventually replace mainframes and minicomputers altogether. Rather than a direct transport of software packages from mainframes to microcomputers, the trend is towards using both technologies simultaneously. The capabilities of microcomputers do not, in general, allow mainframe software to be transported in their entirety to a microcomputer environment. In the case of large centralized data bases, it is not desirable to move the entire mainframe package to a microcomputer. Usually, the original mainframe software is partially hosted in each machine, with communication between them. The offloading of tasks to microcomputers provides for quicker and more efficient user response. In order to handle the growing traffic of information between mainframes and microcomputers on the one hand, and among microcomputers on the other, it is necessary to install special communication links interconnecting the different computing resources. A *Local Area Network* (LAN) is used for this purpose where the computers are in close proximity to each other, e.g., in a single building. Larger distances involve implementation of a *Wide Area Network* (WAN) or the use of a public telecommunication network on a shared basis.

When a communication network is installed, it can also be used for other purposes. The term "electronic mail" refers to various techniques for sending messages electronically by entering them through computers or other automated systems and transmitting them to remote terminals by means of telephone lines, data networks or space satellites. At the receiving end, messages can be immediately read on video terminals, held on file for delayed retrieval or delivery, printed out and distributed as conventional local mail, or even converted to speech. Messages can be in the form of notes, memos, documents, announcements, graphic images, digitized voice, etc. Electronic mail systems are proliferating in many large organizations because of their growing advantages (lower costs, higher speeds, assured delivery and reliability) over conventional systems such as postal services, carriers, and even public telephone services.

Instead of transmitting purely textual information, it is also possible to send pictorial and multilingual documents using *facsimile* techniques. The entire document can be transmitted virtually instantaneously, and the overall cost is roughly comparable to that of a corresponding telephone call.

Facsimile and telex services across international boundaries are provided by carriers, called International Record Carriers (IRC), offering

services between countries on the basis of licences granted by national governments. Many other companies are permitted to carry only voice and data. In almost all cases, the carriers terminate their transmissions either at their own facilities in predesignated gateway cities or at the facilities of the local telecommunications authorities, who hold the exclusive right to data transmission within the country.

Videotext and teletext are examples of new technologies which seem to hold bright promises for applications in health care. Both use the technical infrastructure already provided in many countries by telephone and television networks, and combine them to realize a low-cost system for one-way or two-way transmission of text and colour images between central computers and regional or local offices.

Another advance in this area is teleconferencing. Prototypes are available of systems that permit training to be carried out in remote centres, using videotapes or real-time satellite transmissions. This can be used in informatics training *per se*, but it also offers promise for disseminating medical expertise to remote areas. Currently the equipment necessary to conduct satellite teleconferencing is expensive, but less than long-distance travel.

AT-A-GLANCE

* The essential items to standardize are:
  - data definitions and coding schemes
  - software
  - hardware
  - telecommunications protocols
* The future will offer many technologies giving enhanced or entirely new capabilities, for example:
  - local area networks
  - optical storage media
  - integrated work stations
  - higher level languages
  - wide area networks and data bases
  - enhanced video transmission

6.6 SELECTION METHODOLOGY

The importance of utilizing systematic, objective methods for the selection of computer hardware and software has been gradually recognized, and several competing techniques have been developed for this purpose. One of the most widely employed techniques is the MECCA approach (*Multi-Element Component Comparison and Analysis*), which is a weighted sum technique.

During the selection process, comparisons are made using technical specifications provided by the vendors or manufacturers, or extracted from other publications. However, competing solutions can frequently not be evaluated on the basis of technical specifications alone: a direct comparison based on real performance is necessary. One of the most widely used techniques for comparing the performance of prospective hardware and/or software is called *benchmarking*. In the benchmarking of hardware, a standard program is used to test specific aspects of performance. The programme is run in different machines and the results compared. In other instances, the user tests the speed and efficiency of the same applications software package by running it in different hardware. In the benchmarking of software a processing task is executed by different programs, in the same machine.

A problem common to all kinds of benchmarking is that one needs to have access to programs and/or computers to do the tests. This is sometimes quite difficult to achieve. In these cases, benchmarking is an impractical approach. An alternative approach is to measure performance, capacity, etc., against fixed 'yardsticks' or minimum/maximum criteria or values of com-

parison. This technique is called *monitoring*. Monitoring is easier, but requires longer periods of observation than benchmarking.

6.6.1 The Selection of Software

The selection of the components of a computer system for specific applications will be a direct result of the software capabilities. On the other hand, criteria which are highly dependent on the performance or structure of hardware systems determine which software should be acquired. Therefore, hardware and software are greatly interrelated and should not be selected separately from each other.

There are some fundamental selection criteria for software. With few variations, they should be observed and evaluated every time a selection is to be made:

- ***correctness***: whether the program is error-free, complete, consistent, etc.
- ***adequacy***: whether the software has all the desired functions and will do what the user wants;
- ***integrity***: the capability the software has to resist failures in hardware, invalid data, security breaches, invalid input, etc;
- ***reliability***: the parameter which describes the software's tolerance to errors, accuracy and precision in numerical calculations, consistent behaviour, etc.;
- ***efficiency***: whether the software uses efficiently the available resources of hardware: speed of execution and access, use of memory, access to peripherals, etc.;
- ***usability***: represents the amount of effort necessary to operate the software, such as user training, input speed, ease of operation, ergonomic design, and other factors described under the label "user interface";
- ***testability***: describes the ease with which the software can be tested and/or certified with respect to other properties, such as completeness, integrity, etc.;
- ***maintainability***: describes the possibility and ease of finding the reasons for failure and of recovery from failure, correction of the original program, etc.;
- ***flexibility***: the possibility of modification, adaptation or conversion to respond to the user's needs which are met by the original program;
- ***portability***: describes the effort necessary to transfer or convert a program or software to other hardware;
- ***interoperationality***: describes the possibility and ease to transfer or convert data to or from other software, or to couple two different software packages;
- ***expandability***: the possibility of expanding the software with respect to memory usage, increase in efficiency, addition of new functions, etc.;
- ***ease of installation***: whether the software is easy to install without special procedures, hardware modifications, user's training, etc.;
- ***documentation***: existence and completeness of documentation at the user's and/or programmer's level, whether the documentation is easy to understand, etc.

6.7 DOCUMENTATION

The usefulness of any computer-based information system is directly proportional to the level of usage of that system. In order to promote good usage and provide optimal results, it is essential that proper documentation be established from the initial stage of system development.

At the national level, it is desirable to maintain a roster showing each computer-based information system and the institution at which the system is operational. The roster should show the kind of data and codes used in each system, and the primary application areas.

At the operational sites, additional details should be available at two levels. First, there should be a *user guide* which provides application-oriented details about each piece of software. Step-by-step examples should form an essential part of these user guides. Second, there should be a *reference guide* which contains addi-

tional technical information. A reference guide provides details at the level required to modify or update the application software.

While conducting major surveys, it is desirable to standardize survey forms in advance, and to run the software first using a small sample size. Finally, it should be mentioned that apart from the health organization, other government organizations may also be planning computer-based systems. Standardization and national policies should take into account the requirements of such organizations as well.

Failure to maintain documentation can have severe repercussions. Systems on which the organization is dependent can fail with severe loss of time and the potential inability to recover. It can be difficult or impossible to make needed changes and enhancements. New staff may not be able to operate and maintain existing systems. This can lead to loss of data permanently, errors in programs or data, and the improper execution of functions.

6.8 COSTS AND ACQUISITION

6.8.1 Cost Issues

There are several elements in the cost of this technology. Computers have purchase (hardware) and support (software and personnel) costs; one rule of thumb is that for every dollar spent on hardware, an additional dollar will be spent on support over the ensuing five years. Thus a US$ 1 million hardware investment in a hospital information system will necessitate US$ 200 000 per year carrying costs over the next five years, the useful life of the system.

The costs of technology escalate as changes are forced on the system. It is important to plan a system acquisition thoroughly in advance; retrofitting can be exponentially more expensive than original purchase.

Computers do not often *save* money; rather they make more effective use of resources. Component cost analysis suggests that the health care sector spends too little on informatics; most hospitals provide 1-2% of their resources on data processing, whereas industry often spends 6% on information needs.

The comforting aspect to the cost of informatics is that technical advances are plentiful and continuing. Each year the same resources will acquire 25% more hardware, but 10% less software. This is because software is increasingly more complex and its development is labour intensive. Generally, an informatics specialist will not spend less for hardware *per se*; rather, more powerful equipment will be obtained for the same price.

Telecommunications costs vary very significantly from country to country. In most countries, the rates are determined primarily by the national post, telegraph, and telephone departments, whose rate structures may favour some modes of telecommunications over others.

The myriad of different rate structures can be classified into four broad categories, as follows:

- ***Flat rate structure***: the charge is independent of usage. Usually, the flat rate is based on the distance of communication. A leased line is an example of a flat rate structure;
- ***Measured rate structure***: the charge is based on the duration of the transmission, the time of the day, the day of the week, and the distance. The public telephone network is an example of a measured rate structure;
- ***Tapered rate structure***: there is a minimum monthly rate. As the usage increases, the charge, per unit of time, decreases;
- ***Metered rate structure***: the charge is based on the volume of data transmitted, irrespective of the distance involved. This rate structure is popular among packet switched networks.

It is not easy to estimate the long-term implications of each feasible alternative. Cost, technical compatibility, level of support, and reliability are some of the key factors to be considered. Usually, leased lines and networks are selected by users who have large stable communication needs and who already possess some experience in this area. Less sophisticated users use a dial-

up public network, especially in cases where the communication requirements are relatively modest. The packet switched environment remains the only viable alternative to support large communication needs.

An important cost element associated with the use of informatics and telematics is the manpower cost associated with its operation. All hardware and software will require trained staff, both professional and technical, for operation. The personnel issue has been discussed extensively in Chapter 5. From a cost point of view it is important to recognize that different hardware and software can vary greatly in the cost of operation to perform the same basic functions. For example, the cost of maintaining the operating system for competing minicomputers has been shown to vary by a factor of six. Differential manpower costs are an important aspect of the acquisition decision.

6.8.2 Acquisition

The health manager must go through a process of acquiring information tools. A common approach is to use the Request for Proposal (RFP). The manager gathers a team of interested users and developers and prepares a list of functional requirements for the proposed system. The Financial Manager must assess the current cost of operations to be supported by informatics; this will guide the purchase price and carrying costs of an automated solution. A document based on these needs (the RFP) is developed and sent to potential vendors. This process is repeated until a system solution is developed.

6.8.3 The Maintenance of Hardware

The degree of user dependence on a computer system is extremely variable. At one extreme, the computer is a non-essential tool, and the user can tolerate longer periods of unavailability, or quickly find a substitute for the missing computational power. At the other extreme, the health care organization or computer-based procedure cannot function at all without the computer.

Therefore, in cases where the dependence is great, a permanent contract for technical main-

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tenance of the computer must be arranged. The technical maintenance involves the prevention of failure, as well as the repair of failures occurring in the hardware or operating system. The written contract (usually with the vendor, a technical field representative, or an independent enterprise) calls for certain obligations, such as a minimum response time, penalties for delays, etc. The contract charges the user a fixed amount per month, independent of hardware failure. This amount is usually a percentage of the total cost of the configuration.

The overall reliability of a computer system can be increased by following this advice:

- buy all the components and peripherals from a single vendor;
- select brands and vendors with a consistent history of reliability, quality, service, financial integrity, etc.
- do not buy equipment which cannot be serviced by companies located in your area;
- select hardware tested by the manufacturer under extreme environmental conditions ("burn-in");
- obtain failure statistics;
- buy equipment with a reasonable initial warranty;
- give preference to modular rather than integrated hardware;
- acquire and run diagnostic programs often;
- ensure adequate environmental conditions;
- provide for a permanent contract for technical service.

6.9 CONCLUSION

In recent years, the dividing line between communications technology and computer technology has been gradually disappearing. It has become imperative to delve into the technical details about both these evolving technologies before embarking on any major programme. Adopting the right standards and choosing the appropriate hardware and software are very important to long-term success.

In the endeavour to use the latest technology, local conditions must not be overlooked. For example, the level of the existing telecommunications infrastructure must be taken into account while deciding about interconnection of computers. Similarly, the computers should be equipped with non-stop power supplies and voltage stabilizers in areas where the power supply is erratic.

The field of informatics and telematics will continue to evolve, and new products will become available every year. Planning and implementing strategies for introducing and using contemporary technological aids require technical expertise which can be neglected only at the user's peril. Informatics offers a huge pay-off but must be carefully managed to gain its promising rewards.

AT-A-GLANCE

* Various testing methodologies can reduce the risk associated with major decisions regarding new hardware and software.
* Failure to maintain good documentation may lead to severe problems during operational use.
* Alternatives exist with different costs of informatics and telematics which require careful analysis to minimize expenses for each organization.

Epilogue

As in any study of this type, many subjects of interest to decision-makers could not be covered. This report has concentrated on technical issues associated with the use of informatics in health. For effective management of an organization, the social issues associated with the introduction of informatics may be equally important. These topics were not covered in this report. Some of them are mentioned here.

While it is not clear that introducing computers in a health setting reduces employment, computers will in time alter the pattern of employment. Different skills will be required on existing jobs, and new positions requiring different types of informatics expertise will emerge. To some extent this will lead to fundamental changes in the role of certain health professions. Such changes have already occurred in the case of laboratory technicians, for instance.

The introduction of computers into traditional organizations can be traumatic. Resistance on the part of employees can be quite strong, and even cases of subversion of the system have occurred. Today, most institutions are compelled to assimilate new technology. Unlike many other innovations, however, the introduction of informatics technologies has a systematic impact on the entire organization. Introducing computers requires even more careful attention to change management compared to other technologies.

AT-A-GLANCE

* Organizational social issues associated with the introduction of informatics may be more difficult than the technical issues.

* Informatics will be increasingly used in all organizations and its use must be managed.

Both structural and behavioural changes have to be considered. A strategy is required for both kinds of problems, and the implementation and monitoring of this strategy must be carefully managed. There is strong evidence that organizations which have successfully introduced informatics are more effective and efficient than those which have not attempted it or been unsuccessful in the transition.

The computer itself will raise new social issues. Organization of previously random facts into data bases raises issues of accessibility and privacy that did not seem important before. Health with its data on very personal attributes is particularly sensitive to this phenomenon.

The basic responsibilities of individuals in the organizational hierarchy may not change much but their accountability may change drastically as their performance is more easily measured and observed. The health organization should be much more effective and responsive but the increased discipline implied will be felt by all. Approved accountability is an important contribution made by informatics to improved organizational effectiveness.

Because of this, and its unique technology, the integration of informatics into the overall organization usually presents problems. No universal solutions exist and every organization must solve the problem according to its own circumstances. Permanent organizational arrangements to accommodate informatics may not be possible.

One fact is clear. Organizations cannot avoid issues associated with informatics by doing nothing. The appeal and use of modern informatics technology seem nearly universal. It will be increasingly used in all organizations. Health is no exception. Experience shows that a policy of *laissez-faire* leads to unnecessary complications and problems. Senior management will be forced to plan for informatics or it will be forced to resolve the results of its unplanned use.

Annex 1

International Consultation on Applications of Informatics in Health

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Annex 2

Sample Curricula

I. HEALTH INFORMATICS

Introduction to Health Informatics

An introduction to the knowledge and skills expected of a professional working in the field of health informatics. The basic concepts of the field are established, the methodologies used are investigated, and the people involved and their organizational settings are introduced. The flow and use of data and information within the health care system are highlighted.

Hospital Information Systems

Introduces the student to different types of systems which support health care professionals. Topics include: management information systems, patient classification systems, management engineering, resource allocation, physician office systems, word processing.

Patient Care Support Systems

Provides a broad understanding of the role and impact of computers on indirect patient care support and shows the potential for continued integration. Specific medical computer languages are introduced. Topics include: laboratory systems, image processing, ambulatory systems and telemedicine.

Distributed Processing in Health Care

A management perspective to data communications technology, networks, and distributed processing. Emphasis is on examining the impact of emerging communications and microcomputer technology on information systems in various sectors of the health care delivery system.

Quantitative Methods in Health Services

Introduces a range of analytical modelling techniques useful in health care decision-making. Covers the problems of data collection, maintenance and accuracy when using models to assist decision-making activities. Topics include: operations research, allocation problems, linear programming, scheduling, queueing models, inventory models.

Additional courses for consideration as part of a curriculum would include:

- computer structures and languages
- systems analysis
- database and information retrieval
- data and file structures
- technology assessment
- expert systems.

II. HEALTH DEVELOPMENT

Health Law

Presents the process and principles of law that apply to health and discusses the relevant legislation, regulations and guidelines. The content includes governmental organization, process and principles of law specific to the health setting, licensing of health care personnel, invasion of privacy, confidentiality, security, medical record issues, social implications of general availability of health information issues in record linkage, and ethical use of technology.

Health Data Generation and Classification

Examines the sources of health data and their collection, storage, retrieval, and control. An appreciation of the limitations, accuracy, and completeness of information. Alternative methods of obtaining information. Relative size, volume, frequency of collection, and volatility of data elements. Problems of standardization and aggregation. Topics also include: development of medical records, common laboratory and radiological procedures and medication prescriptions, nomenclatures and nosologies, terminology, disease classification systems, Medline and Index Medicus.

Medical Methodology

Analyses the process of clinical decision-making in diagnosis, treatment planning and prognosis. Alternative models for clinical decision-making using subjective and objective data and information. Investigates diagnostic systems, patient management, investigation, therapy and the effects and interaction of drugs. Includes history-taking examination of body systems, problem list creation and diagnosis. Emphasis is on the need to understand mechanisms underlying the patient's clinical signs and symptoms in order to develop, on a national basis, the clinical diagnosis and patient strategy. Covers the principles of general physiology and anatomy, including a systematic discussion of normal and abnormal human physiology and pathophysiology of common disease processes and a basic understanding of the effects, side-effects, mechanism of action, and interaction of drugs.

Epidemiology

Introduction of epidemiological principles and examples of the application of these principles to the monitoring of disease occurrence, epidemiological investigation, disease control, and health programme evaluation. Examples from acute and chronic diseases, environmental and occupational health are used. Epidemiological research methods are studied, from problem conceptualization and design to analysis. The course studies relevant design and analysis techniques, using packaged programs, such as Statistical Package for the Social Sciences (SPSS) and Biomedical Computer Programs (BMCP).

Quality Assurance and Ethics

Provides an in-depth assessment of the quality, interpretation and use of health data in the area of direct patient care. Students analyze the data elements and the methodologies used to assess such factors as quality, social impact, and clinical significance. The ethical and confidentiality issues encountered are examined.

Elective courses could include:

- health economics
- quality assurance and ethics
- community health/primary health care
- intersectoral coordination in health.

III. MANAGERIAL PROCESSES FOR NATIONAL HEALTH DEVELOPMENT

Introduction to Health Care Delivery

An overview of the organization, operation and administration of the health care delivery system, which provides the student with an understanding of how the multiple components and interrelationships are integrated. Describes the public policies, issues, trends and forces that have influenced the development of the system. Examines the training, values and roles of the professionals working within the health care delivery system. Topics also include: health care organizations, delivery alternatives, providers, suppliers, consumers, financiers, regulators, planning and evaluation, costs, and cost containment.

Hospital Organization and Management

The course presents an analysis of the structure and nature of hospitals as organizations, and provides insight into the nature of human behaviour in hospitals as a function of individual and group interaction, and the structure and environment of the total organization. The roles, values, and training of the various health professionals are covered.

Fiscal Management in Health Services

An examination of the systems and financial reporting required to support management decision-making in health care delivery. Topics include: institutional accounting and budgeting, provincial and federal governme requirements, clinical programme budgeting.

Programme Evaluation

The application of scientific evaluation methodologies in the study and analysis of clinical and management information systems. Topics include: problem formulation, selection of research design, data and organizational analysis, and interpretation.

Health Care Systems

An examination of the structure and function of the current health delivery system, particularly from the point of view of how information flow influences health caretrends and policy formulation. Emphasisis is on community, regional, provincial and national information flows. Constraints and needs are identified. Topics include: government health data bases, cancer registries, occupational and environmental health, record linkage.

Project Management

This course exposes the student to important issues in the management of a computing project in a health care delivery setting. Topics include: project management theory and techniques, cost estimating and budgeting, planning and control, monitoring and evaluation, financing of computer equipment, services and functions, contract negotiations, management and procurement procedures, development of an RFI (request for information) and an RFP (request for proposal), salesmanship, needs definition, committee structures, proposal evaluations, system design, training and orientation.

Annex 3

Glossary

Except for definitions standardized by International Organization for Standardization (ISO), these are for the reader's convenience only and should not be considered as official WHO definitions. The terms in capital letters are the most important ones for readers unfamiliar with informatics terminology.

accountability Liability to be called to account for actions for which one is responsible.

ACM Association for Computing Machinery.

algorithm A finite set of well-defined rules for the solution of a problem in a finite number of steps. Example: A full statement of an arithmetic procedure for evaluating sin x to a stated precision (ISO 2382/1-1974)

APPLICATION The use of an information system or software package for a particular purpose or in a special way.

architecture The selection, design and interconnection of the physical components of a computer system.

ARTIFICIAL INTELLIGENCE The concept that computers can be programmed to assume some capabilities normally thought to be like human intelligence, such as learning, adaptation, and self-correction.

ASCII American Standard Code for Information Interchange, a character code for representing data.

asynchronous In communications, transmission which is not dependent on the synchronization of timing or frequency between the two nodes; the start and end of the messages transmitted are encoded in the transmission.

attribute In programming, a characteristic of an entity.

baseband Refers to transmission of signals in their original unmodulated form through access control of the communication line.

bit Either of the digits 0 and 1 when it is used in the pure binary numeration system (ISO 2382/IV-1974). *See* byte.

bit map Screen memory such that each pixel corresponds to one bit in memory for monochrome screens or several bits for colour screens.

BMCP Biomedical Computer Program, a statistics software package.

broadband Refers to transmission of signals in a frequency-modulated fashion, over a segment of the total bandwidth available, thereby permitting simultaneous transmission of several messages.

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bus A common pathway shared by signals from several components of the computer.

byte A set of eight bits, which is normally the smallest number of bits required for representing an alphanumerical character in the computer's memory. *See* bit.

CATV Cable television.

CCITT Consultative Committee on International Telegraph and Telephone.

CD/ROM *See* compact disk/read only memory.

CENTRAL PROCESSING UNIT A unit of a computer that includes circuits controlling the interpretation and execution of instructions (ISO 2382/1-1974).

code A set of unambiguous rules that establish a character set and the one-to- one relationships between the characters of the character set and their coded representations

compact disk/read only memory Also popularly called "laser disks", compact disks are used to store large amounts of data (around the equivalent of 220 000 pages of text). As the name indicates, these disks can only be read by the end-user (not recorded on to), with the help of a device called a compact disk (or laser disk) drive. *See also* optical disk.

COMPATIBILITY The ability for computer programs and computer readable data to be transferred from one hardware system to another without losses, changes or extra programming.

COMPUTER A data processor that can perform substantial computation, including numerous arithmetic operations or logic operations, without intervention by a human operator during a run (ISO 2382/1-1974).

CONFIGURATION The particular choice of hardware and its connections making up a computer system.

connectivity The ability of disparate devices to be connected into a single system.

CPU *See* central processing unit.

DATA A representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means (ISO 2382/1-1974).

DATA BASE A collection of structured data. The structure of the data is independent of any particular application (BCS Glossary 1985).

DATA BASE MANAGEMENT SYSTEM A set of programs for establishing, sorting, searching and otherwise manipulating the data base. It generally permits further calculations and the production of reports.

data dictionary The set of standard descriptions of data items and entities which are used in all programs in an organization. It includes definitions, codes, validation rules, ownership, right of access, right of updating.

data element data item.

data transcription *See* transcribe.

DBMS *See* data base management system.

decision support system A management information system in which significant analysis is done in order to present reports in a format directly useful for decision.

DISK A flat circular plate with a magnetizable surface layer on which data can be stored by magnetic recording (ISO 2382/XII-1978).

distributed data base A data base which, though conceived as one whole, is held in more than one computer. Normally, most of the data files are stored closest to the main user but shared by all.

DSS *See* decision support system.

duplex A transmission system allowing data to be transmitted in both directions simultaneously.

EDP See electronic data processing.

electronic data processing Data processing largely performed by electronic devices (ISO 2382/1-1974).

ELECTRONIC MAIL A system for transmitting documents and messages between computer terminals by means of computer communication links.

E-mail *See* electronic mail.

entity An object of interest which can be described by a group of elementary data items.

EXPERT SYSTEM A computer system containing organized knowledge so that it can perform some of the functions of an expert human consultant.

facsimile A process of digitizing a page, transmitting the resulting bit stream, and reconstituting the original material.

FEASIBILITY STUDY The stage in the implementation of a computer system when estimates of the cost and effort involved in implementing a full system are made.

FLOPPY DISK A flexible magnetic disk enclosed in a protective container (ISO 2382/XII-1978).

format The arrangement or layout of data on a data medium (ISO 2382/IV-1974).

GB *See* gigabyte.

gigabyte 1024 megabytes, approximately one billion (10^9) bytes.

HARD DISK A rigid disk with much greater memory capacity than a floppy disk, usually permanently sealed in its drive unit.

HARDWARE Physical equipment used in data processing, as opposed to computer programs, procedures, rules and associated documentation (ISO 2382/I-1974).

IC *See* integrated circuit.

IMIA International Medical Informatics Association.

IMPLEMENTATION The process of developing and putting a system into operation.

INFORMATICS A comprehensive term covering all aspects of the development and operation of information systems, the supporting computer methodology and technology, and the supporting telecommunication links.

information centre An organizational entity charged with providing general support services to users of information systems.

information retrieval The action of recovering information on a given matter from stored data (ISO 2382/I-1974).

information system A system for the collection, storage, processing and dissemination of information to the users, which may or may not be computerized.

input Data being received or the process of receiving data into a data processing system or part thereof.

integrated circuit A solid state microcircuit consisting of interconnected semiconductor elements diffused into a single device.

INTERFACE The boundary between two hardware or software systems across which data are transferred. An overall term to refer to the physical linkages and procedures, codes and protocols that enable meaningful exchange of programs, commands or data between two computerized systems or devices.

ISO International Organization for Standardization.

ITU International Telecommunication Union.

keyboard A set of keys in a typewriter-like arrangement used to enter data or commands into the computer.

LAN *See* local area network.

LANGUAGE A set of characters, conventions, and rules used for conveying information (ISO 2382/VII-1977).

laser card A data recording device similar to an optical disk but in a card form.

laser disk See compact disk/read only memory.

light pen A device with a photoelectric cell whose location on a screen can be detected and used as input, e.g., to select from a menu or to draw a shape.

local area network A high-speed geographically constrained (e.g., office complex) communications arrangement between computing equipment permitting data transfer, sharing of common resources and convenient physical connections to the users.

MAINFRAME A computer with a variety of peripheral devices, a large amount of storage and a fast central processing unit, generally used for comparison with a smaller or subordinate computer.

management science The application of scientific methods to the study of management generally through the application of quantitative techniques.

MB *See* megabyte.

megabyte 1024 x 1024 or 1 048 576 bytes, approximately one million bytes.

menu Options displayed on the screen to lead the user through a program.

menu-driven Describes a program whose use is controlled by a series of menus.

MICROCOMPUTER A complete small computer system built around a microprocessor CPU.

microfiche A microscopic photographic copy of text or graphic data.

microprocessor A special integrated circuit which contains, in a single chip, all the elements of a central processing unit, and which is normally used as the CPU of a microcomputer.

MINICOMPUTER A computer whose size, speed and capability lie between a mainframe and a microcomputer.

modem MOdulator-DEModulator. A device at the end of an analog communications line for translating digital signals into analogue form and vice versa.

module A small program which can be compiled separately and linked to form part of a large program.

monitor A functional unit that observes and records selected activities within a data processing system for analysis. NOTE: possible uses are to indicate significant departure from the norm, or to determine levels of utilization of particular functional units (ISO 2382/XI-1976). Also, popularly used as a term to refer to a visual display unit.

mouse An input device which, when moved over a flat surface, moves the cursor on a VDU.

NETWORK A set of computers and peripherals connected by communications links.

NLM National Library of Medicine.

node A station on a network where one or more devices can be connected.

objective The ultimate goal to be achieved when undertaking various tasks and activities.

OFFICE AUTOMATION The use of computer-based technology for the purpose of increasing productivity of office workers.

offline Pertaining to the operation of a functional unit when not under the direct control of the computer (ISO2382/X-1979).

online processing Processing performed on equipment directly under the control of the central processor, while the user remains in communication with the computer.

OPERATING SYSTEM Software for controlling the execution of computer programs and that may provide scheduling, debugging, input/output control, accounting, compilation, storage allocation, data management, and related services (ISO 2382/I-1974).

operations research The design of models for complex problems concerning the optimal allocation of available resources, and the application of mathematical methods to the solution of those problems. (ISO 2382/I-1974)

optical disk A high capacity and rapid response memory device using a laser record and read technique. *See also* compact disk/read only memory.

output (noun) The process that consists of the delivery of data from a data processing system or from any part of it (ISO 2382/VI-1974).

PACKAGE A set of commercially available programs designed for a specific use.

packet A short block of data containing information on its source, content and destination which is the unit transferred in a packet switched network.

packet switched network A communication network in which packets are transmitted to particular receivers.

PDN *See* public data network.

PERIPHERAL EQUIPMENT In a data processing system, any equipment, distinct from the central processing unit, which may provide the system with outside communication or additional facilities (ISO2382/I-1974).

pixel The smallest dot or picture element which can be coded into an electrical signal.

PROCESSOR In a computer, a functional unit that interprets and executes instructions (ISO 2382/X-1979). *See also* microprocessor.

PROGRAM (noun) A schedule or plan that specifies actions which may or may not be taken. A program expressed in a form suitable for execution by a computer (ISO 2382/I-1974).

program (verb) To design, write, and test programs (ISO 2382/I-1974).

PROGRAMMER-ANALYST A professional position in which the capabilities of a programmer are combined with some functions of the systems analyst.

PROTOCOL The formal rules governing the exchange of information in a communication link including format, timing, sequencing and error control.

public data network Public service provided by governments or companies, which consists in the supply of communication channels for data transmission, which technically allow the interconnection of computers of an entire region or country.

RAM *See* random access memory.

random access memory (RAM) Memory which is used for temporary storage of programs and data and is erased when the power of the computer is shut off.

read only memory (ROM) A storage device whose contents cannot be modified, except by a particular user, or when operating under particular conditions. Example : a storage device in which writing is prevented by a lockout (ISO2382/XII-1978).

requirements analysis The first stage in the development of a computer application in which the system is described in terms of the problem to be solved and the benefits to be derived from its solution.

retrieval *See* information retrieval.

ROM *See* read only memory.

RS232C A technical specification controlling the connection of data terminal equipment to data communication equipment.

secondary storage Storage or memory which is not located in the central processor of the computer but is in peripheral media such as tapes, disks, diskettes, etc.

SECURITY The establishment and application of safeguards to protect data, software and computer hardware from accidental or intentional modification, destruction or disclosure.

soft disk *See* floppy disk.

SOFTWARE Computer programs, procedures, rules and any associated documentation concerned with the operation of a data processing system (ISO 2382/I-1974).

SPREADSHEET A program which is based on the use of tables whose entries can be text, numbers, or formulas relating to other locations in the table.

SPSS Statistical Package for the Social Sciences, a statistics software package.

start bit A bit signalling the start of an asynchronous serial transmission.

stop bit A bit signalling the end of an asynchronous serial transmission.

strategy A set of activities chosen in order to achieve long-term goals.

synchronous Pertaining to two or more processes that depend upon the occurrence of a specific event such as a common timing signal (ISO 2382/X-1979).

SYSTEMS ANALYSIS The process of defining and determining the behaviour of a system for purposes of problem identification, problem selection and systems design.

TELECOMMUNICATIONS The transmission and reception of messages over a distance, e.g., using radio, telephone lines.

TELEMATICS The use of computer-based information processing in telecommunications and the use of telecommunications to allow computers to transfer programs and data to one another.

telemedecine The use of telematics to transmit medical data.

teletext A computer-based information retrieval system which uses screen messages broadcast by television or provided interactively through a cable system.

telex A process of digital telecommunication of alphanumeric characters.

terminal An input-output unit by which a user communicates with a data processing system (ISO2382/XI-1976).

throughput The amount of work performed by a computer system over a given period of time.

touch panel A computer input device in which switches are activated by touching a sensitized surface.

transaction A short interaction between a computer and an operator for a specific purpose, such as recording a payment or entering a name.

transcribe To transfer data from one data medium to another, converting them as necessary for acceptance by the receiving medium (ISO 2382/IV-1974).

V24 CCITT standard for defining the modem to data terminal equipment interchange circuit.

validation A process of testing data by applying criteria to them to determine whether they are suitable for entry into a data base.

VDU See visual display unit.

videotext See teletext.

visual display unit (VDU) A terminal device incorporating a cathode ray tube on which text can be displayed.

Winchester disk See hard disk.

WORD PROCESSING An automated computer-based method for creating, editing, formatting and display/printing the written word.

WORK STATION A specialized terminal with some independent data processing capability.

WP See word processing.

X.Protocol A CCITT standard that specifies the interface between data terminal and packet switching data circuit terminating equipment.

X.25 A standard defining the interface between a PDN and a packet mode user device.

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The use of informatics in health has expanded enormously over the past few years, the greatest impact being seen in the medical field. However, experience with the use of the technology in some areas of the health sector, such as primary health care and public health, is still quite limited. Considerable interest in the potential of informatics has been expressed by staff of national health authorities, and there is an increasing awareness of the ability of informatics to improve the quality and cost-effectiveness of health services and support activities.

It is hoped that this book will help health service staff to appreciate the ways in which informatics technology has evolved and its potential for the future. With such an understanding, they will be better equipped to select and introduce the systems most appropriate to the needs of the various parts of the health care system.

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